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Geology of
Limerick and Tudor Townships
Hastings County

By

S. B. LUMBERS

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CONTENTS

PAGE

- Abstract vii
- Introduction 1
  - Present Geological Survey 1
  - Acknowledgments 2
  - Means of Access 2
  - Natural Resources and Development 3
  - Previous Geological Work 3
- Physiography and Pleistocene Geology 4
  - Physiography 4
    - Relief 4
    - Drainage 5
    - Rock Exposure 6
  - Pleistocene Geology 6
    - Direction of Ice Movement 6
    - Glacial Deposits 7
    - Other Deposits 7
- Bedrock Geology 8
  - Preliminary Statement 8
  - Metavolcanics and Metasediments 10
    - Metavolcanics 10
      - Nomenclature 11
      - Lithology 12
        - Mafic Metavolcanics 12
        - Felsic Metavolcanics 16
        - Mafic Dikes 18
    - Metasediments 18
      - Nomenclature 18
      - Lithology 20
        - Clastic Siliceous Metasediments 20
        - Calcareous Metasandstone and Metasiltstone 25
        - Carbonate Metasediments 26
    - Stratigraphy 30
      - General 30
      - Tudor Metavolcanics 31
      - Oak Lake Formation 31
      - Vansickle Formation 32
      - Turriff Metavolcanics 32
      - Burnt Lake Formation 32
      - Dungannon Formation 32
  - Intrusive Rocks 33
    - Sodic Granitic and Syenitic Rocks 33
      - General 33
      - Glanmire Complex 36
      - Beaver Creek Complex 37
      - Wendsley Lake Albite Granite 38
      - Minor Albite Granite and Syenite Stocks 38
      - Trondhjemite Stocks 38
    - Mafic Intrusive Rocks 39
      - General 39
      - Lingham Lake Complex 41
      - Tudor Gabbro 42
      - Thanet Complex 43
      - Jocko Lake Complex 44
      - Umfraville Gabbro 45
      - Minor Mafic Intrusions 46
    - Mafic Sills and Dikes 47
    - Potassic Granitic and Syenitic Rocks 47
  - Paleozoic Sedimentary Rocks 48
    - Shadow Lake Formation 49
  - Late Calcite and Quartz Fissure Veins 49
  - Comparison of Bedrock Geology to Aeromagnetic Data 50

PAGE
Structural Geology 52
    Folding 52
    Faulting 53
Economic Geology 55
  Introduction 55
    Prospecting and Mining Activity 55
  Base and Precious Metal Mineralization 58
    Rusty-Weathering Schists 58
    Other Pyrite and Pyrrhotite Mineralization 62
    Gold and Arsenic 62
      Description of Deposits 63
          Craig Mine 63
          McMurray Occurrence 65
          Quinlan Lake Occurrence 68
          Lot 5, Concession XIII, Tudor Township 68
          Lot 4, Concession I, Tudor Township 68
          Arsenopyrite in the Lingham Lake Complex 68
          Lot 11, Concession XIII, Tudor Township 69
          Lot 4, Concession XIV, Tudor Township 69
          Lot 5, Concession XV, Tudor Township 69
          Quartz Veins in the Glanmire Complex 69
          Lot 9, Concession VII, Limerick Township 70
          Other Occurrences 70
    Copper and Nickel 70
      Description of Deposits 72
          Macassa Gold Mines Limited 72
          Triana Exploration Limited 76
    Iron and Titanium 77
      Description of Deposits 78
        Contact Metasomatic Deposits 78
          St. Charles Mine 78
          Glanmire Lake 80
          Lee Mine 80
          Baker Mine 80
          Emily Mine 82
          Lot 3, Concession XIX, Tudor Township 83
        Iron Formation 83
        Magmatic Segregation Deposits 84
          Orton Mine 84
          Lots 41, 42, 54 and 55, East, and Lot 55, West of the Hastings Road 85
          Lots 27 and 28, Concession XV, Limerick Township 86
        Other Deposits 86
          Lot 8, Concession XV, Tudor Township 86
          Ricketts Iron Mine 87
    Lead and Zinc 87
      Description of Deposits 88
          Stewart Lead Occurrence 88
          Lot 11, Concession II, Tudor Township 88
          William Ramsey 89
          Lots 11 and 12, West of Hastings Road 90
          Lot 33, Concession III, Tudor Township 90
          Lot 20, West of the Hastings Road 90
          Lot 10, Concession V, Tudor Township 90
          Lot 29, Concession XIV, Tudor Township 91
          Bouzan Mines Limited 91
          Roberts Lead Occurrence 92
          Reelman Occurrence 93
          Lot 23, Concession B, Tudor Township 93
          Lot 28, Concession B, Tudor Township 93
          Lot 30, Concession B, Tudor Township 93
          Lot 15, West of Hastings Road 94
          Murphy Mine 94
          Lot 34, Concession IV, Tudor Township 94
          Other Occurrences 94
    Silver 95
    Bismuth 95

PAGE
Nonmetallic Minerals and Industrially Useful Rocks 96
Barite 96
Talc and Tremolite 96
Marble 96
Massive Metavolcanics 98
Sand and Gravel 98
Marl 98
References Cited 99
Index 102

Tables

1–Table of formations 8
2–Chemical analyses and norms of metavolcanics 15
3–Generalized subdivision of the carbonate metasediments 19
4–Generalized subdivision of calcareous metasandstone and metasiltstone group 21
5–Modal and chemical compositions of metasediments 22
6–Modal and chemical compositions of sodic granitic and sodic syenitic rocks 34
7–Modal and chemical compositions of gabbros and diorites 40
8–Chemical analyses of rusty schists from Tudor Township 60
9–Spectrographic analyses of rusty schists and metasediments 61
10–Spectrographic analyses of magnetic opaque fractions from rocks of the Thanet, Jocko Lake, Tudor, Umfraville, and Beaver Creek intrusions 71
11–Chemical analyses of mineralized samples from the Orton Mine 86

Photographs

1–Amphibole-rich metavolcanics showing well developed foliation in parts of flows 13
2–Layered amphibolite 13
3–Mafic pyroclastic rocks and layered biotite amphibolite 14
4–Flow layering in metarhyolite 17
5–Felsic lapilli metatuff 17
6–Very thick-bedded metasubarkose interbedded with feldspathic metagreywacke 24
7–Rhythmically bedded polymictic metaconglomerate and feldspathic metagreywacke 24
8–Interbedded marble and porphyroblastic actinolite metasediments 25
9–Typical fine-grained marble 27
10–Typical fine- to medium-grained marble 27
11–Contaminated intrusive breccia of the Glanmire Complex 36
12–Nests of potassic, syenite pegmatite intruded into intrusive breccia of the Glanmire Complex 37
13–Discontinuous compositional layering in uralitized gabbro of the Tudor Gabbro 43

Figures

1–Key map showing location of map-area vii
2–Generalized Pleistocene geology .... Chart A, back pocket
3–Aeromagnetic data superimposed on general lithology .... Chart A, back pocket
4–Stratigraphy, structure and metamorphism .... Chart A, back pocket
5–Sketch map showing patented land, The International Nickel Co. of Canada Ltd. 57
6–Sketch map of the geology and workings, McMurray occurrence 66

PAGE
7–Surface plan showing the general geology and mineralized zones, Macassa Gold Mines Ltd. 73
8–Vertical section through the main mineralized zone, Macassa Gold Mines Ltd. 74
9–Sketch map of the geology and workings, St. Charles mine 79
10–Sketch map of the geology and workings, Baker mine 81
11–Sketch map of the surface showings, Orton mine 85

Geological Maps and Chart
(back pocket)

Map 2167 (coloured)–Limerick Township, Hastings County.
Scale, 1 inch to ½ mile.
Map 2168 (coloured)–Tudor Township, Hastings County.
Scale, 1 inch to ½ mile.
Chart A (coloured)–Figure 2, Figure 3, Figure 4.

ABSTRACT

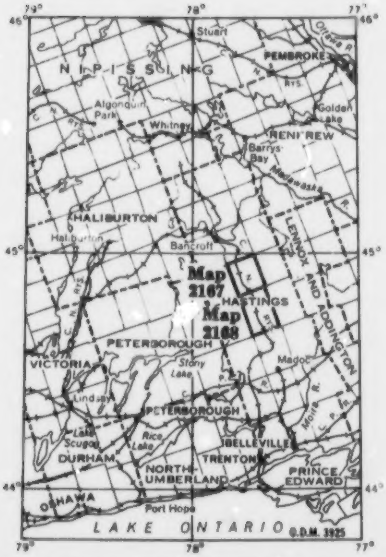
79°
78°
77°
46°
45°
44°
Stuart
Ottawa R.
PEMBROKE
N I P I S S I N G
C. N. RYS.
Algonquin Park
Whitney
Golden Lake
RENFREW
Barrys Bay
Madawaska R.
HALIBURTON
Haliburton
Bancroft
LENNOX AND ADDINGTON
Map 2167
HASTINGS
Map 2168
PETERBOROUGH
Madoc
VICTORIA
Stony Lake
Lindsay
PETERBOROUGH
Moira R.
C. P. R.
Lake Scugog
Rice Lake
BELLEVILLE
DURHAM
TRENTON
NORTH-UMBERLAND
PRINCE EDWARD
OSHAWA
Port Hope
LAKE ONTARIO
O.D.M. 3925

Figure 1–Key map showing location of map-area. Scale, 1 inch to 50 miles.

Limerick and Tudor Townships are near the southwest border of the Grenville Province of the Canadian Precambrian Shield. Both townships are underlain largely by a Proterozoic metavolcanic-metasedimentary sequence about 27,000 feet thick, which was regionally metamorphosed to the greenschist facies in Tudor Township and southern Limerick Township and to the lower and middle almandine amphibolite facies in central and northern Limerick Township. The regional metamorphism culminated after the sequence was folded about northeast-trending axes; the oldest rocks exposed display the lowest grades of metamorphism.

Formations can be traced in the metavolcanic-metasedimentary sequence, and two main divisions are recognized: 1) a predominantly metavolcanic group divided into five formations and consisting in the lower part of mafic and minor felsic metavolcanics (about 1,310 ± 15 million years old) and in the upper part of predominantly felsic and intermediate metavolcanics, metasandstones, and polymictic metaconglomerate; and 2) an extensive unit rich in carbonate metasediments, the lower part of which interfingers with, or is equivalent to, the upper part of the metavolcanic group. The upper part of the carbonate metasedimentary unit comprises the youngest rocks of the metavolcanic-metasedimentary sequence whose base is unknown. The volcanic rocks were extruded into a dominantly marine environment in which was deposited the carbonate metasedimentary unit. Although much of the clastic

siliceous material was eroded from nearby highlands of dacitic and felsic volcanic rocks, some was eroded from a sedimentary terrain, possibly either an older, more distal part of the geosynclinal tract, or basement rocks.

Several intrusive stocks were emplaced within the metasediments and metavolcanics with accompanying contact metamorphism, and consist of two major groups: 1) an early sodic group, about 1,250 ± 25 million years old, characterized by high soda to potassia ratios; and 2) a late potassic group characterized by low soda to potassia ratios. The oldest members of the sodic group, epizonal albite granite and syenite stocks, were emplaced before the culmination of the regional metamorphism, but other members of the group, trondhjemite stocks and mafic complexes, were emplaced after the culmination of the regional metamorphism. Mafic sills and dikes, which are concentrated near a zone of major faulting, were intruded after the sodic group of intrusions but before the potassic group of intrusions. A gabbro-rich stock of the potassic group, which intruded a trondhjemite stock of the sodic group, is only slightly younger than 1,250 ± 25 million years.

A small outlier of the Middle Ordovician Shadow Lake Formation is poorly exposed in the southeast corner of Tudor Township, and in Tudor Township and southern Limerick Township calcite and quartz fissure veins, which are found locally in the Proterozoic rocks, are younger than the Middle Ordovician and appear to be related to late northwest-trending faults. The area was subjected to Pleistocene glaciation, and Recent deposits consist of swamp accumulations, marl, and local fluvial and lacustrine deposits.

Pyrite- and pyrrhotite-bearing, rusty-weathering schist zones, which are at least in part of hydrothermal origin, are common throughout the map-area in intensely deformed rocks. Copper, nickel, gold, arsenic, iron, titanium, lead, zinc, silver, bismuth, barite, and talc mineralization are present. The nickel and most of the copper mineralization are associated with metapyroxenite phases of sodic group mafic complexes, which contain abundant quartz-bearing diorite and tonalite. Gold and arsenic mineralization are confined mainly to quartz veins within greenschist facies metavolcanics, and most of the lead, zinc, and barite mineralization are found in late calcite fissure veins. Silver mineralization accompanies the gold, arsenic, lead, and zinc mineralization. Iron mineralization is found as: 1) siliceous iron formation associated with metavolcanics; 2) low titanium contact metasomatic deposits developed in carbonate metasediments next to sodic group intrusions; and 3) high titanium magmatic segregation deposits within gabbro-rich stocks. Several types of marble and massive, middle greenschist facies metavolcanics are potential sources of building stone and terrazzo aggregate.

Geology of

Limerick and Tudor Townships

Hastings County

By

S. B. Lumbers[1]

INTRODUCTION

Limerick and Tudor Townships cover an area of about 176 square miles in the central part of Hastings County and are shown on the Coe Hill, Bannockburn, and Kaladar map sheets of the National Topographic series. The villages of Gilmour, St. Ola, and Millbridge are the main centres of population, and the post offices and settlements of Ormsby, Steenburg, and Murphy Corners lie within the area.

Mineral exploration and some mining have been carried out in the area for over 100 years. Mining activity has been confined mainly to Tudor Township where small tonnages of lead and iron ores and some gold were produced during the last half of the 1800s and the early part of the 1900s. Copper and nickel mineralization in ultramafic intrusive rocks were discovered in the map-area between 1957 and 1961, and have been explored by surface trenching and by diamond-drilling.

Present Geological Survey

Geological mapping of Limerick and Tudor Townships was carried out by the author and his assistants during the 1961 and 1962 field seasons. Mapping was done by pace-and-compass traverses, generally run at ¼-mile intervals, perpendicular to the strike of the various rock units. Owing to the abundance of topographic control, such as fields, roads, streams, and lakes, picketed baselines were rarely run. Most of the geological data gathered were plotted in the field directly on acetate sheets fitted over 4 inch to the mile air photographs.

Geological data were transferred from the air photographs to basemaps, on a scale of 1 inch to 1,320 feet, prepared by the Cartographic Unit of the Ontario Department of Mines from maps of the Forest Resources Inventory of the Ontario Department of Lands and Forests. Topographic additions and alterations were made to the basemaps by the author. The final maps are reproduced on a scale of 1 inch to ½ mile (Maps 2167 and 2168, back pocket).

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[1] Geologist, Ontario Department of Mines, Toronto. Manuscript received by Chief Geologist 13 July, 1966.

Outcrop areas visited by the geologists and used for the geological interpretation of the area are shown on Maps 2167 and 2168 (back pocket). Some of these outcrop areas consist almost entirely of continuous rock exposure, whereas others consist of many small outcrops. The time and resources available to the geologists made necessary fewer detailed lithological and structural observations in forested areas, where outcrops are commonly obscured by lichens, moss, and forest litter, than in fields or along waterways where outcrops are generally clear of vegetal cover.

Over 1,100 rock hand specimens were collected by the geologists in the two townships for petrographic and chemical examination. The results of these laboratory studies supplemented field observations and aided in preparing the classification of the rocks that is shown by symbols on Maps 2167 and 2168 (back pocket).

Acknowledgments

During the 1961 field season the author was assisted by D.D. Brown, R.J. Ross, J.A.R. Brothers, and K.A. Maclean. In 1962, the author's assistants were D.D. Brown, J.D. Scott, P.E.C. Reed, and R.A. Tivy. Mr. Brown, as a senior assistant during both field seasons, did independent geological mapping. Some independent geological mapping in southern Tudor Township was done by Mr. Maclean. P.S. Ray assisted the author with some of the laboratory studies.

Numerous residents of the area rendered assistance in many ways for which the author is indebted to them. Mr. L.H. Wright, Deputy Chief Ranger, Ontario Department of Lands and Forests, Gilmour, stored equipment for the author between the 1961 and 1962 field seasons. Mr. Stan Stangl of Howard Smith Paper Mills Limited, Gilmour Division, allowed the field party to use the company's private roads in Limerick Township.

Mr. J.D. Bryce, president of Macassa Gold Mines Limited, and Mr. Cyril Holland, chief geologist, Bicroft Division, Macassa Gold Mines Limited, aided the author in his study of Macassa's nickel property, near Ormsby, by contributing drill hole and assay data, and by permitting the author to examine drill core from this property.

Some laboratory studies for this report were carried out by the author at the Department of Geology, Princeton University.

Means of Access

During the latter half of the nineteenth century, the major means of access to the area was by the Hastings Road and the Snow Road. At present, most of the area, except parts of eastern Tudor Township and northeastern Limerick Township, is easily accessible by motor roads. Highway 62 and the Canadian National Railways line from Trenton Junction to Bancroft pass through the west-central part of the area. A spur line of the railway extends westward from Ormsby Junction to Coe Hill[1], and Highway 620 extends westward from Highway 62 through Coe Hill to Apsley. Township roads service most parts of the area. Private motor roads constructed by Howard Smith Paper Mills Limited give access to many parts of northeastern Limerick Township. Most of the area not accessible by motor roads can be reached on foot or by tractor along trails and old logging roads.

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[1] This spur line now has been abandoned and the rails removed.

Natural Resources and Development

The Hastings colonization road opened the area for settlement in the 1850s; by the 1870s numerous farms had been cleared, and the villages of Gilmour, St. Ola, and Millbridge had been established as lumbering and agricultural communities. Subdivision of the two townships into lots and concessions was commenced in 1850 and completed in 1862. The Canadian National Railways line that passes through the area was opened to Coe Hill in 1884 and was completed north from Ormsby Junction to Maynooth in 1901.

Many of the farms established by the settlers have now been abandoned, and for agricultural purposes, most of the land can be classified as either marginal, or submarginal. The only prosperous farms in the area are those underlain by the Paleozoic outlier in the southeast corner of Tudor Township. Hay and oats are the chief crops, and sheep, cattle, and pigs are raised.

Commercial stands of spruce, pine, balsam, cedar, hemlock, poplar, maple, beach, ironwood, and birch are a major source of income in the area. Although pulpwood is the principal forest product, railway ties and sawn, rough, and dressed lumber were produced at the five sawmills that were active in the area during 1961 and 1962.

Summer residents and hunters provide the other major sources of income in the area. Bass, pickerel, trout, perch, and pike are commonly caught in the lakes and streams, and white-tailed deer, black bear, weasel, mink, skunk, muskrat, rabbit, beaver, and fox are the common game and fur-bearing animals of the district.

Previous Geological Work

Barlow (1899) and Miller and Knight (1913) carried out the first detailed geological mapping in the area, but no other detailed mapping was done in the area until the present study. Reconnaissance studies were carried out in the area by Macfarlane (1866), Vennor (1870), Adams and Barlow (1910), Chayes (1942), and Thomson (1943). Other references to the geology of the map-area are found in Hewitt (1956), Rose (1958), and in Laakso (1961). Preliminary geological maps of Limerick and Tudor Townships compiled by the author were published in 1962 and 1963 (Lumbers 1962; 1963).

The Coe Hill (G.S.C. 1950a), Bannockburn (G.S.C. 1950b), and Kaladar (G.S.C. 1952) aeromagnetic sheets include the map-area, and Abraham (1951) and Harding (1951) describe aeromagnetic anomalies in the area.

PHYSIOGRAPHY AND PLEISTOCENE GEOLOGY

PHYSIOGRAPHY

The map-area lies within the Cashel peneplane division of the Lake Ontario homocline (Kay 1942a). This homocline forms the northern limit of the Allegheny synclinorium (Kay 1942b) and is a south-sloping surface that was deeply eroded in Precambrian time. Paleozoic outliers are common along the southern border of the Cashel peneplane, and it is probable that the whole peneplane was once mantled by early Paleozoic sedimentary rocks. Only one Paleozoic outlier occurs in the map-area, in the southeast corner of Tudor Township.

RELIEF

The Cashel peneplane is a resurrected, glaciated, Precambrian erosion surface with a local relief of about 100 feet and a gentle southward slope averaging about 7 feet to the mile (Kay 1942a). The maximum relief in Tudor Township and in Limerick Township is 300 feet, and in the map-area as a whole, it is about 500 feet. A group of ridges underlain by metagreywacke and some marble, less than 1 mile south of Egan Lake in northeastern Limerick Township, have elevations up to 1,350 feet above sea-level, which is the highest elevation in the map-area. The lowest elevations in the area are along the southern boundary of Tudor Township, where the average elevation is 900 feet above sea-level. Northward from the southern boundary of Tudor Township the average elevation gradually increases so that in the central part of Tudor Township it is about 1,000 feet; at the northern boundary of Tudor Township it is 1,050 feet; in central Limerick Township it is 1,150 to 1,200 feet; and at the northern boundary of Limerick Township the average elevation is 1,100 to 1,150 feet above sea-level. This gradual increase in average elevation from south to north in the map-area is locally interrupted by resistant rock masses with higher average elevations than those of the surrounding country. These resistant rock masses are mainly plutonic rocks. The Tudor Gabbro, with a local relief of up to 200 feet, is the best example in the map-area of such a mass.

The grain of the topography closely conforms to the layering and foliation of the underlying rocks, particularly where these rocks are predominantly medium- to coarse-grained marble and metagreywacke. The topography of the area underlain by metasediments north of Limerick Lake in eastern Limerick Township differs markedly from the flat to gently rolling topography characteristic of most of the areas underlain by metasediments in these townships. Here, numerous northeast-trending ridges underlain by medium- to coarse-grained marble and metagreywacke have a local relief of 50 to 100 feet. These ridges appear to be the surficial expression of complex flowage folds overturned to the east. Rough and irregular topography is characteristic of most of the areas underlain by plutonic rocks. Gabbroic bodies have an especially rough and irregular topographic expression, with many small swampy depressions that are commonly joint controlled. Most of the plutonic rocks of the area show up on the topographic maps as irregular topography with average elevations of 50 to 100 feet greater than that of the surrounding country.

Most of the lake basins occur at contacts between marble and rocks more resistant to erosion than marble. Some lake basins originated in part as solution basins; others, such as Robinson and Brinklow Lakes in Limerick Township, lie in the cores of synclinal folds developed in underlying metasediments. Small sink holes and solution cavities, generally joint controlled and with no visible sedimentary fillings, are common in the fine-grained marbles in southern and western Tudor Township.

DRAINAGE

The map-area is drained by three drainage systems; the Moira River system, the Trent River system, and the Madawaska River system. The Madawaska River system is part of the Ottawa River drainage basin; the other two river systems belong to the Lake Ontario drainage basin. The water parting which separates the Ottawa River drainage basin from the Lake Ontario drainage basin passes south of the Umfraville Gabbro, Jocko Lake, and Bea Lake in Limerick Township, and extends into Cashel Township, to the east of Limerick Township, just north of the Blue Sea Lakes (see Figure 2, Chart A, back pocket). Although irregular in detail, the general trend of the water parting in the Haliburton-Bancroft region parallels the major northwest-trending normal faults in the Madawaska highlands.

The eastern and southern parts of Tudor Township are drained by the Moira River system and its main tributaries, the Jordan River and West Black River. The remainder of Tudor Township and all but the northern third of Limerick Township are drained by the Trent River system via its main tributaries, Beaver Creek and the Deer River. The northern third of Limerick Township is drained by the Madawaska River system via Egan Creek which joins the York River in central Dungannon Township to the north of Limerick Township. Most of these waterways are not navigable in the map-area because of rapids, waterfalls, and log jams; the waterways connecting Dixon, Dark, and St. Ola Lakes with Limerick Lake are easily navigable by small boat. Most of the main tributaries to the river systems that drain the map-area are consequent upon the resurrected Precambrian erosional surface. In places the courses of these main tributaries have been altered by Pleistocene deposits. Hewitt and James (1955) note one such alteration in the course of the York River in Dungannon Township. Within the map-area, Pleistocene deposits apparently have not affected the courses of the major tributaries. Some of the low order tributaries to the major streams in the area, however, have been profoundly altered by glacial and glaciofluvial deposits, and now present a typical deranged pattern. In those parts of the area with a high percentage of rock exposure the drainage pattern is roughly rectangular and is probably controlled by jointing in the bedrock.

Many of the small streams of the area, particularly those draining regions underlain by plutonic and volcanic rocks, have been dammed by beavers. The resulting flooding of these streams has created numerous small ponds and swampy areas, or has enlarged previously existing ponds.

ROCK EXPOSURE

Rock exposure in the area ranges between 15 and 70 percent. Glacial deposits and glaciofluvial deposits are not abundant but lacustrine deposits and swampy areas are widespread. The plutonic and metavolcanic rocks are generally well exposed; the metasediments are poorly exposed in places, particularly metagreywacke in southern Tudor Township. Many streams and swampy depressions occur in areas underlain by marbles or along contacts between marble and plutonic rocks, marble and metavolcanic rocks, or marble and metagreywacke. Where thin layers of marble occur between layers of other metasediments or between layers of metavolcanics, the marble is generally poorly exposed because of its greater solubility. The largest swampy areas are found in areas underlain by metavolcanics and by metagreywacke, both of which have well developed joint sets; in places, particularly in southern Tudor Township, metagreywacke exposures consist mainly of broken and slightly displaced blocks of variable size. The Umfraville Gabbro and other plutonic rocks, generally well exposed in the map-area south of the water parting in Limerick Township, are not well exposed north of the water parting because of a marked increase in the amount of sand deposits.

PLEISTOCENE GEOLOGY

Many physiographic features in the map-area owe their origin to Pleistocene continental glaciation. Although study of Pleistocene deposits in the Great Lakes region indicates four glacial stages during the Pleistocene Epoch, evidence of only the last stage, the Wisconsin, is found within the map-area. Two major lobes of the Wisconsin ice-sheet have been recognized in the central and eastern parts of southern Ontario (Chapman and Putnam 1951): the Lake Ontario lobe, which advanced westward into the Lake Ontario Basin from the St. Lawrence and Ottawa valleys; and the Northern lobe, which advanced southward across the central part of southern Ontario to the Lake Ontario Basin. The orientation of glacial striae and of drumlins indicate that the map-area was affected only by the Northern lobe. The main features of the Pleistocene geology in Tudor and Limerick Townships are shown in Figure 2 (Chart A, back pocket).

DIRECTION OF ICE MOVEMENT

Within the map-area, the average direction of ice movement determined from eight glacial striae is S6°W. Three drumlins in Tudor Township and one in Wollaston Township, west of Limerick Township, have an average trend of S4°W. The average trend of glacial striae within the map-area is similar to that in neighbouring areas; in the Madoc and Marmora areas eighteen striae on Wilson's (1940a and b) maps have an average trend of S9°W and in the Grimsthorpe-Barrie area striae trend S10°W to S15°W (Meen 1942, p. 24).

GLACIAL DEPOSITS

Glacial deposits within the map-area consist of till in the form of ground moraine and drumlins. The till of the ground moraine is commonly a gravelly to sandy loam containing numerous pebbles and boulders derived from Precambrian rocks. In the southeast corner of Tudor Township, till has been derived largely from underlying red and grey shale, limestone, and sandstone of Ordovician age. Throughout the area the ground moraine is generally not more than a few feet thick, but rare thicker accumulations are found in valleys and in depressions between rock ridges. North of the water parting in Limerick Township the ground moraine is commonly thicker and more extensive than south of the parting. The ground moraine also appears to thicken slightly in southern Tudor Township, down the slope of the Cashel peneplane.

Podzolic soils have formed on much of the ground moraine; where marble is the predominant bedrock, brown forest soils are common. Details of soil types and their distribution within Hastings County are given by Gillespie *et al.* (1962).

The three drumlins in Tudor Township are slender in plan and taper at both ends. They rise to a maximum height of 100 feet above the surrounding country, are 1.25 to 2.5 miles long, and are 0.1 mile to 0.25 mile wide. Till that forms the drumlins is poorly exposed; it appears to be mainly boulder and pebble loam, with the boulders and pebbles derived locally from Precambrian rocks. The origin of these drumlins requires further study, but the slender shape indicates that the ice-sheet responsible for their formation contained only a slight excess load over that which the glacier was capable of transporting. No evidence was found to indicate that the drumlins had been overridden by a second ice-sheet. These drumlins are similar in many respects to drumlinoid ridges described by Dean (1953) and Prest (1963).

OTHER DEPOSITS

Numerous small deposits of sand and gravel overlie, and in places are interstratified with, the ground moraine. Most abundant north of the water parting in Limerick Township, these deposits show bedding and many are found at the borders of swampy areas and along stream valleys. Some of these deposits, particularly those north of the water parting, are of glaciofluvial origin, whereas others are of glaciolacustrine origin. Among the thickest sand and gravel deposits in the area are those along the valley of Steenburg Creek, between Steenburg and Limerick Lakes. These deposits have been used extensively for local road construction.

Thinly bedded varved clays are rarely exposed around lakes and in stream valleys; one of the most extensive areas of varved clay is between Dixon Lake and the eastern end of Limerick Lake in eastern Limerick Township. When the last ice disappeared, many of the lakes in the area were probably larger than at present. Clay and silt were washed into lakes and depressions from adjacent bare hills, and as vegetation took hold, these low areas were partly to wholly converted to bogs. Muck soils and peat now predominate in swampy areas, and in some lakes and bogs overlying marble, marl has accumulated. Egan Lake and the Blue Sea Lakes contain notable marl deposits (see "Marl" section).

BEDROCK GEOLOGY

PRELIMINARY STATEMENT

Limerick and Tudor Townships are in the central part of the Bancroft-Madoc area (Lumbers 1964; 1967a and b) of the Grenville Province of the Canadian Precambrian Shield. Both townships are underlain by a Proterozoic complex (Silver and Lumbers 1966) consisting of metavolcanics and metasediments which increase in metamorphic grade from south to north in the area, and a large variety of intrusive rocks which form numerous stocks exposed over areas ranging from a few thousand square feet to about 30 square miles. Formations can be traced in the metasediments and metavolcanics, and six units are recognized, which in approximate order of decreasing relative age are: 1) Tudor metavolcanics consisting mainly of mafic metavolcanics and whose base is unknown; 2) Oak Lake formation consisting mainly of intermediate and felsic metavolcanics; 3) Vansickle formation consisting mainly of poorly sorted feldspathic metasandstone, metaconglomerate, calcareous metasandstone and metasiltstone, and minor metavolcanics; 4) Turriff metavolcanics consisting of mafic and felsic metavolcanics; 5) Burnt Lake formation consisting of mafic metavolcanics; and 6) the Dungannon formation consisting mainly of carbonate metasediments. The oldest intrusive rocks which were emplaced before the culmination of the regional metamorphism are albite granite and syenite, and minor gabbro, diorite, trondhjemite, and granodiorite. Dioritic complexes, containing late trondhjemite and granodiorite phases, and trondhjemite stocks were emplaced after the culmination of the regional metamorphism but before the emplacement of mafic sills and dikes which are localized in the central part of the area. A gabbroic complex in northwestern Limerick Township, which contains a late potassic syenite phase, and other bodies of potassic syenite and quartz monzonite are probably the youngest intrusions in the area. Middle Ordovician sedimentary rocks are exposed in a small outlier in the southeast corner of Tudor Township, and post-Middle Ordovician calcite and quartz fissure veins are found locally in Tudor Township and southern Limerick Township.

Table 1 | TABLE OF FORMATIONS

CENOZOIC

RECENT

Swamp, lake, and stream deposits; marl

PLEISTOCENE

Varved clay, sandy and silty boulder clay, sand, pebble gravel, boulder gravel

Unconformity

POST-MIDDLE ORDOVICIAN

LATE CALCITE AND QUARTZ FISSURE VEINS

Intrusive contact (?)

PALEOZOIC

ORDOVICIAN

Quartz-rich, red siltstone and sandstone, arkose, polymictic conglomerate

Unconformity

PROTEROZOIC

INTRUSIVE ROCKS

Potassic Granitic and Syenitic Rocks

Potassic granite, quartz monzonite, potassic syenite, monzonite, granite pegmatite and syenite pegmatite dikes, granite pegmatite and syenite pegmatite nests

Mafic Sills and Dikes

Altered gabbro and altered diorite

Mafic Intrusive Rocks

Peridotite and metaperidotite, pyroxenite and metapyroxenite, olivine gabbro, gabbro, diorite, altered gabbro and diorite, anorthositic gabbro and diorite, anorthosite, hornblende diorite, quartz-bearing diorite, tonalite, fine-grained mafic dikes, hybrid diorite

Sodic Granitic and Syenitic Rocks

Albite granite, hybrid albite granite, fine-grained albite granite, sodic granite, albite syenite, amphibole-rich albite syenite, fine-grained albite syenite, trondhjemite, amphibole trondhjemite, contaminated trondhjemite, granodiorite, contaminated intrusive breccia

Intrusive contact

METASEDIMENTS AND METAVOLCANICS

Carbonate Metasediments

Marble, phlogopitic and tremolite marble, calc-silicate granofels and gneiss, amphibole granofels, diopside granofels, tactite, layered diopside hornfels, talc rock

Calcareous Metasandstone and Metasiltstone

Calcareous feldspathic metagreywacke, porphyroblastic actinolite metasediments, porphyroblastic hornblende metasediments, para-amphibolite, layered amphibole hornfels

Clastic Siliceous Metasediments

Feldspathic metagreywacke, meta-arkose, metasubarkose, polymictic metaconglomerate

Felsic Metavolcanics

Felsic flow rocks, felsic tuff and lapilli tuff, felsic agglomerate

Mafic Metavolcanics

Amphibole-poor mafic metavolcanics, amphibole-rich metavolcanics, layered amphibolite, layered biotite amphibolite, hornblende-quartz-plagioclase gneiss, mafic pyroclastic rocks, siliceous iron formation

METAVOLCANICS AND METASEDIMENTS

The metavolcanics and metasediments are lithologically classified into several varieties on the basis of: 1) mineral compositions, 2) grade of metamorphism, and 3) preserved, primary microtextures and megastructures; available data permit general interpretations of the primary lithology and of the origin of these rocks. In Maps 2167 and 2168 (back pocket), iron formation layers are shown in black and rusty-weathering, pyrite- and pyrrhotite-bearing schist units which developed in both the metavolcanics and metasediments are shown in brown.

Mineral assemblages of the metavolcanics and metasediments show that their regional metamorphic grade increases in intensity from the greenschist facies in Tudor Township and southern Limerick Township to the almandine amphibolite facies in central and northern Limerick Township. Plagioclase in all the regionally metamorphosed metavolcanics and metasediments becomes progressively more calcic from south to north in the map-area and ranges in composition from albite in Tudor Township to andesine in northern Limerick Township. On the basis of the plagioclase composition, three isograds are defined in the metavolcanics and metasediments (Figure 4)[1]: 1) a zoned albite isograd which marks the boundary between middle and upper greenschist facies rocks, the disappearance of most primary microtextures in the metasediments and metavolcanics, and is coincident with the garnet isograd in metasediments of suitable bulk chemical composition, 2) an oligoclase isograd which marks the boundary between upper greenschist and almandine amphibolite facies rocks, and is coincident with the staurolite isograd in rocks of suitable bulk chemical composition; and 3) an andesine isograd which marks the boundary between lower and middle almandine amphibolite facies rocks, and the first appearance of diopside and andalusite in rocks of suitable bulk chemical composition. Mineral assemblages of the middle greenschist facies rocks are most typical of the quartz-albite-epidote-biotite subfacies of the greenschist facies of Turner (Fyfe *et al.* 1958, p. 217-224); upper greenschist facies rocks can be correlated with Turner's quartz-albite-epidote-almandine subfacies. Further data are needed to correlate the almandine amphibolite facies rocks with specific subfacies; mineral assemblages of the lower almandine amphibolite facies rocks are most typical of Turner's staurolite-quartz subfacies. Near most intrusions, the metavolcanics and metasediments show well developed contact metamorphic aureoles. In the greenschist facies terrane, the aureoles are zoned with an outer zone of albite-epidote hornfels facies rocks and an inner zone of hornblende hornfels facies rocks; in the almandine amphibolite facies terrane, rocks of the aureoles were metamorphosed to the hornblende hornfels facies.

Metavolcanics

Within the map-area, mafic and minor felsic metavolcanics form four major sequences: 1) in north-central and eastern Tudor Township and the southeast corner of Limerick Township; 2) in northwestern Tudor Township south of Brett Lake; 3) within the complex Murphy Corners Anticline (Figure 4) in central and northern Limerick Township, and 4) within the Robinson Lake Syncline

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[1] (Chart A, back pocket.)

(Figure 4) in west-central Limerick Township. In addition to the major sequences, minor metavolcanic units are interbedded with carbonate-poor metasediments southeast of Steenburg Lake and west of Beaver Creek in northern Tudor Township, and near St. Ola in southern Limerick Township.

NOMENCLATURE

Metamorphism of the metavolcanics, which has caused almost complete alteration of primary mineral assemblages, does not allow the use of volcanic rock classifications that are based upon petrographic criteria. Nevertheless, by combining petrographic and field studies, the author is able to distinguish mafic flow rocks, mafic pyroclastic rocks, felsic flow rocks, and felsic pyroclastic rocks. Mineralogical variations due to metamorphism and to primary differences in composition characterize each of these four main classes.

Mafic flow rocks are further subdivided according to secondary mineralogy as follows:

Primary rock	*Greenschist facies regional metamorphism*	*Contact metamorphism*	*Lower and middle almandine amphibolite facies regional metamorphism*
Basalt and andesite	*Amphibole-rich metavolcanics*	*Contact metamorphic amphibolite*	*Foliated and layered amphibolite*
Andesite and dacite	*Amphibole-poor mafic metavolcanics*	*Contact metamorphic amphibolite*	*Hornblende-quartz-plagioclase gneiss and layered biotite amphibolite*

Felsic metavolcanics and mafic pyroclastic rocks are subdivided according to their primary structural and textural relationships. Metatuff is generally laminated to thin-bedded and contains rare metavolcanic fragments whose average size is less than 4 millimetres; lapilli metatuff contains numerous metavolcanic fragments whose sizes range between 4 and 32 millimetres. Meta-agglomerate contains numerous metavolcanic fragments whose average size is greater than 32 millimetres. Felsic flow rocks are generally leucocratic, massive to well foliated, and commonly contain large grains of quartz and feldspar in a sericitized, fine-grained groundmass.

LITHOLOGY

Mafic Metavolcanics

In Tudor Township and southeastern Limerick Township, where the metavolcanics were metamorphosed to the middle greenschist facies, most of the mafic metavolcanics were derived from basaltic and andesitic flows. Amphibole-rich metavolcanics form most of the metavolcanic sequence in the north-central and eastern parts of the township; locally, near the top of this sequence, in the vicinity of felsic metavolcanic units and in the metavolcanic sequence south of Brett Lake, amphibole-poor mafic metavolcanics are abundant. Amphibole-rich metavolcanics are fine- to medium-grained, massive to foliated, green to dark-green rocks whose major constituents in approximate order of decreasing abundance are actinolite, albite, epidote, quartz, and iron-titanium oxide minerals; accessory minerals are carbonate, chlorite, apatite, sphene, biotite, pyrite, pyrrhotite, and rarely, chalcopyrite. Amphibole-poor mafic metavolcanics are fine- to medium-grained, massive to foliated, greyish-green rocks which commonly contain biotite and magnetite porphyroblasts, and, rarely, a few, scattered, medium- to coarse-grained actinolite porphyroblasts. In approximate order of decreasing abundance, the major constituents of these rocks are albite, quartz, biotite, chlorite, epidote, and iron-titanium oxide minerals; accessory minerals are carbonate, actinolite, white mica, and pyrite.

Both types of mafic flow rocks display a variety of primary textures and structures such as grain gradation within flows, phenocrysts of altered plagioclase, amygdules, flow top breccia, and pillows; in thin section, poorly foliated to massive varieties show primary, subophitic and intergranular textures. Porphyritic varieties are particularly abundant in a northeast-trending zone, ½ to ¾ mile wide and 4½ miles long, that extends from the Tudor Gabbro contact in lots 17 and 18, concessions XI and XII, to the Moira River in lots 5 and 6, concessions XV and XVI, Tudor Township. Pillowed flows, in which the pillow structures are generally deformed and only rarely sufficiently well preserved to give dependable top determinations, are abundant, but individual flows which range in thickness from 5 to 30 feet were rarely recognized. Foliation is best developed in the fine-grained parts of flows (Photo 1). Quartz-carbonate lenses and veinlets which are generally less than 1 foot wide, which commonly contain traces of pyrite, pyrrhotite, and chalcopyrite, and which are aligned parallel to the foliation, are widespread, particularly throughout the amphibole-rich metavolcanics. Carbonatized and sericitized zones up to 1½ miles wide are present in the mafic metavolcanics where felsic metavolcanics are abundant.

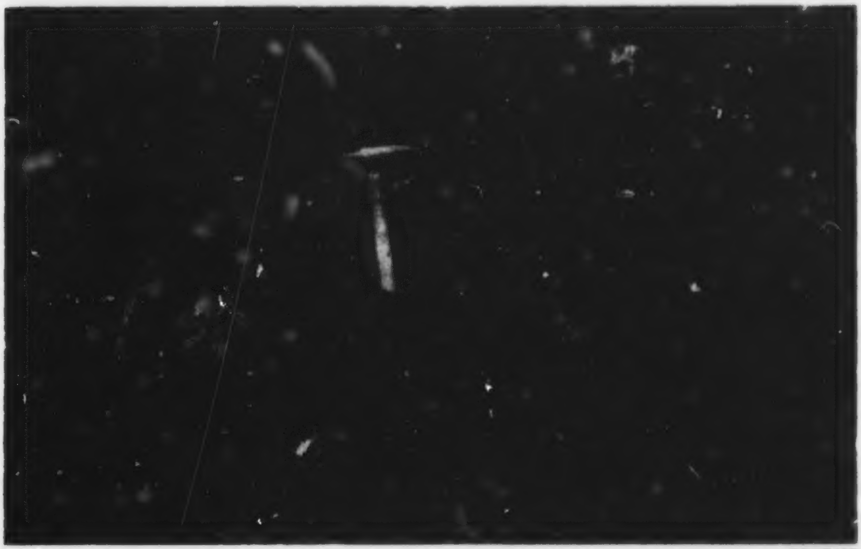
In Limerick Township, the almandine amphibolite facies regional metamorphism converted the mafic flow rocks into various types of amphibolite. Foliated amphibolite, the most abundant mafic flow rock, is dark-green and contains rare, medium-grained porphyroblasts of garnet and hornblende in a fine-grained groundmass composed mainly of oriented hornblende prisms in a granular quartz-plagioclase matrix which generally contains minor epidote and carbonate. The amphibolites display mineral layering near intrusions and contacts with metasediments and where metavolcanic units are either thin, or show marked changes in strike. Layers are commonly discontinuous and are either plagioclase

ODM7495

Photo 1–Amphibole-rich metavolcanics showing well developed foliation in the fine-grained parts of flows, roadside rock cut, Highway 62, lot 16, concession XV, Tudor Township.

ODM7496

Photo 2–Layered amphibolite containing hornblende aggregates in a quartz-plagioclase host, lot 21, concession XIII, Limerick Township.



ODM7497

Photo 3–Mafic pyroclastic rocks and layered biotite amphibolite. Elliptical shaped masses in layer to left of hammer are epidotized bombs. Lot 21, concession XIII, Limerick Township.

layers generally less than a half inch thick in a mafic-rich host, or hornblende aggregates in a quartz-plagioclase host (Photo 2). Foliated amphibolite commonly grades into layered amphibolite, which is a dark-green to greyish-green rock containing numerous medium- to coarse-grained hornblende porphyroblasts in a granular quartz-plagioclase matrix. Layered biotite amphibolite, which was derived probably from andesitic and dacitic flows, is most abundant in the west limb of the Murphy Corners Anticline and near felsic metavolcanic and pyroclastic units (Photo 3). Quartz, plagioclase, garnet, and carbonate are more abundant than in the other amphibolite types, and biotite, which is generally concentrated in hornblende-rich layers, forms more than 10 percent of the rock. Locally, layered biotite amphibolite grades into hornblende-quartz-plagioclase gneiss and into garnetiferous, biotite-plagioclase-quartz gneiss which is probably derived from felsic tuff. Poorly preserved, primary volcanic structures are common in the foliated amphibolite but are rare in the amphibolites containing mineral layering.

Mafic pyroclastic rocks are rare and consist of lapilli tuff and agglomerate. In Tudor Township and southeastern Limerick Township, mafic pyroclastic units as much as 8 feet thick contain mafic metavolcanic fragments and epidotized lapilli and bombs in a fine-grained, foliated, biotite- and chlorite-rich matrix. Fragments are commonly deformed, and a few amphibole-poor and amphibole-rich metavolcanic flows are interbedded with the pyroclastic units. In Limerick Township, almandine amphibolite facies mafic pyroclastic units, which are commonly associated with layered biotite amphibolite, contain poorly preserved epidotized bombs and lapilli in a compositionally layered matrix rich in biotite and which contains less than 20 percent hornblende.

Near intrusions in Tudor Township, contact metamorphism of the mafic flow rocks produced poorly foliated to massive, dark-green, fine-grained amphibolites which locally contain thin, discontinuous, quartz-plagioclase layers. Primary volcanic structures are rare and granoblastic texture is common. These rocks contain more sphene and more accessory sulphide minerals, particularly chalcopyrite, than the regionally metamorphosed mafic flow rocks, and discordant, undeformed, quartz veins, which rarely contain visible mineralization, are common. The largest vein found is the auriferous vein at the Craig mine (see "Craig Mine" section). In Limerick Township, mafic metavolcanics near intrusions rarely have a granoblastic texture, but rusty schist zones are common. Discordant quartz veins are smaller, more contorted, and less abundant than in contact metamorphic amphibolites in Tudor Township.

Table 2 CHEMICAL ANALYSES AND NORMS OF METAVOLCANICS

SAMPLE NUMBER	1	2	3
	CHEMICAL ANALYSES, IN WEIGHT PERCENT		
SiO_2	48.10	46.34	52.98
Al_2O_3	17.14	19.31	14.28
Fe_2O_3	6.69	5.80	3.50
FeO	11.83	10.14	8.60
MgO	4.33	1.13	4.66
CaO	7.09	10.22	7.51
Na_2O	2.68	2.07	4.36
K_2O	0.48	1.00	0.31
H_2O+	2.00*	2.08*	1.09
H_2O-			0.06
CO_2	....	....	0.31
TiO_2	....	....	2.13
P_2O_5	....	....	0.25
MnO	....	....	0.16
Total	100.34	98.09	100.20
	C.I.P.W. NORMS		
Quartz	2.06	2.44	3.83
Orthoclase	2.83	6.22	1.83
Albite	22.59	18.13	36.82
Anorthite	33.20	40.78	18.45
Enstatite	10.08	2.13	6.11
Ferrosilite	16.14	10.49	9.67
Diopside	1.44	9.22	11.80
Ilmenite	....	..	4.04
Magnetite	9.67	8.84	5.07
Calcite	....	....	0.70
Apatite	....	....	0.59
H_2O	1.99	2.11	1.09
Total	100.00	100.00	100.00

*In samples 1 and 2, H_2O+ and H_2O- are combined.

SAMPLES:

1 and 2–Amphibole-rich metavolcanics, Tudor metavolcanics, lot 12, concession XV, Tudor Township (Miller and Knight 1913, p. 84).

3–Pillowed, foliated amphibolite, Turriff metavolcanics, lot 21, concession XVI, Limerick Township (James 1957). Analysis by J. H. Scoon.

Chemical analyses of mafic metavolcanics for which petrographic data are available are given in Table 2. These analyses show that amphibole mafic metavolcanics are basalts with relatively high ratios of Fe_2O_3:FeO, but one analysis of foliated amphibolite may represent a spilite. The extent to which the regional metamorphism may have altered the original composition of the metabasalts is unknown, and all the Fe_2O_3 may not be *original* oxidation.

Felsic Metavolcanics

Felsic flow rock units, which commonly contain minor pyroclastic rocks and rarely show flow layering (Photo 4), are mainly oval in shape, but a few units appear to be tabular. In Tudor Township, some units show local intrusive relationships with adjacent mafic metavolcanics. Felsic flow rocks generally weather light-grey to white, they are light-grey to black on an unweathered surface, and they are commonly foliated and sericitized. Greenschist facies felsic flow rocks in Tudor Township and southeastern Limerick Township are partly mylonitized, and massive; aphanitic varieties that have a conchoidal fracture, relic feldspar phenocrysts, and relic felty and trachytic microtextures are abundant; in almandine amphibolite facies felsic flow rocks in Limerick Township, primary microtextures are largely destroyed, but primary features such as relic feldspar phenocrysts and flow layering are present. The felsic flow rocks are composed mainly of feldspar, quartz, white mica, and biotite; common accessory minerals are carbonate, apatite, and opaque minerals. Greenschist facies varieties rarely contain porphyroblasts of garnet and chloritoid, but almandine amphibolite facies varieties contain porphyroblasts of garnet, muscovite, biotite, and, rarely, andalusite.

Petrographic data indicate that the felsic flow rocks were derived mainly from potassic and sodic rhyolites and from potassic and sodic trachytes. Rhyolite predominates over trachyte, which is poor in quartz, and sodic rhyolite and sodic trachyte, which are poor in potassic feldspar, are more abundant than potassic varieties of these rocks. In northeastern Tudor Township, a thin, persistent, felsic metavolcanic unit, which has been traced by the author along strike for about 8 miles, contains massive to foliated metavolcanics that closely resemble the felsic flow rocks but which may be welded tuffs.

Felsic pyroclastic rocks consist of metamorphosed tuff, lapilli tuff, and agglomerate which are commonly interlayered with one another. Interbedded locally with the metatuff are black fine-grained rusty-weathering laminated rocks containing a few grunerite or cummingtonite porphyroblasts and as much as 25 percent graphite and pyrite. These rocks may represent carbonaceous black shales in a tuff sequence, and except for the laminated habit, rare amphibole porphyroblasts, lack of pyrrhotite and more graphite and quartz, they are similar to rusty schists (see "Rusty-Weathering Schists" section). Other tuffaceous rocks closely resemble feldspathic metagreywacke (see "Clastic Siliceous Metasediments") but are thin-bedded to laminated. Agglomerate and lapilli tuff (Photo 5) contain angular to rounded, felsic metavolcanic fragments, which are commonly deformed by shearing, in a fine-grained foliated, quartzo-feldspathic matrix commonly rich in biotite and muscovite. In the almandine amphibolite

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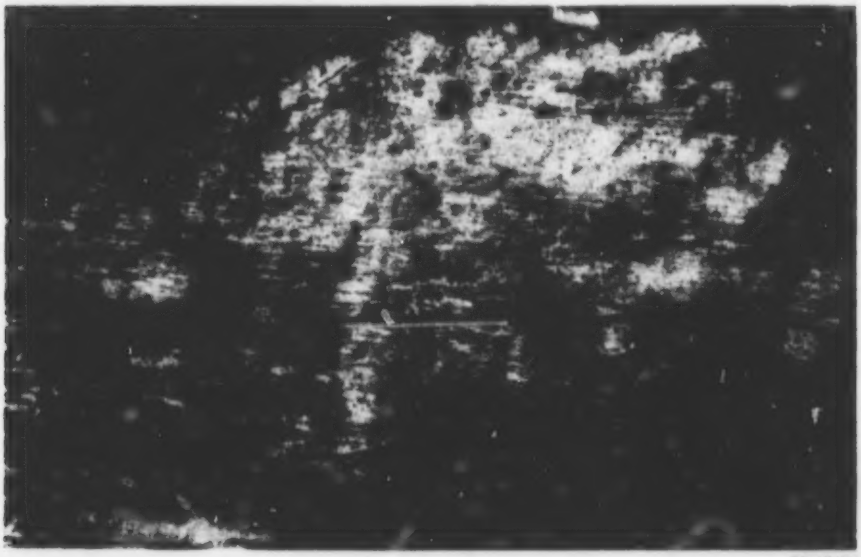
Photo 4–Flow layering (parallel to hammer handle) in metarhyolite, lot 21, concession XIII, Limerick Township.



ODM7499

Photo 5–Felsic lapilli metatuff, lot 21, concession XIII, Limerick Township.

facies terrane staurolite is present rarely in metatuff units, and some tuffaceous rocks were metamorphosed to porphyroblastic, garnet-biotite-plagioclase-quartz gneiss.

Mafic Dikes

A few metamorphosed, foliated, mafic dikes found in the metavolcanic sequences may have been emplaced during the periods of volcanism and could be feeders to mafic flows. These dikes are generally less than 3 feet wide, and although they trend at a high angle to the foliation in the host metavolcanics, their foliation is parallel commonly to the foliation in the metavolcanics.

Metasediments

Metasediments underlie about a third of Tudor Township and over half of Limerick Township, and five main groups are recognized:

Group	Primary Rock Types	Types of Sedimentation
Clastic siliceous metasediments	Conglomerate, sandstone, siltstone, and rare shale	Clastic
Carbonate metasediments	Impure limestone and dolostone	Chemical and biochemical
Calcareous metasandstone and metasiltstone	Calcareous sandstone and siltstone and sandy and silty limestone and dolostone	Clastic and chemical (transitional between first two groups)
Iron formation	Chert with iron-rich layers	Chemical and biochemical(?) in a reducing environment
Graphitic and pyritiferous slate and schist	Black shale	Clastic and biochemical(?) in a reducing environment

Metasediments of the third group, which is transitional between the first two groups, are progressively decarbonatized with increasing metamorphic grade, and in Limerick Township these rocks are characterized by abundant amphibole. Iron formation is discussed in the Economic Geology section, and, as described earlier, graphitic and pyritiferous slate and schist are interbedded locally with metatuff.

NOMENCLATURE

Clastic siliceous metasediments, which contain less than 10 percent amphibole and less than 30 percent carbonate, are composed mainly of quartz, feldspar, mica, and chlorite, and they have a conspicuous megascopic clastic texture. The majority of these rocks were derived from sandstones and silty sandstones, but a few were derived from intraformational conglomerate and polymictic orthoconglomerate which contains a variety of metasedimentary and a few metavolcanic fragments. If mica and chlorite that are present in the sand-sized clastic

Table 3 GENERALIZED SUBDIVISION OF THE CARBONATE METASEDIMENTS IN LIMERICK AND TUDOR TOWNSHIPS

PRIMARY ROCK TYPE	METAMORPHIC FACIES	CARBONATE CONTENT (VOLUME PERCENT)	GRAPHITE	AVERAGE GRAIN SIZE OF CALCITE IN MM	Ca-Mg, Ca-Al, AND Mg SILICATE MINERALS (VOLUME PERCENT)	TEXTURE	ROCK NAME
A. REGIONAL AND CONTACT METAMORPHISM; METASOMATISM ABSENT OR MINOR							
Limestone and dolostone (clastic, non-carbonate minerals less than 10 percent)	Middle and upper greenschist	>70	Abundant dust-like particles	<0.5	Phlogopite, tremolite, chlorite (<10)	Massive to foliated	Fine-grained marble
	Upper greenschist, lower almandine amphibolite, and albite-epidote hornfels	>70	Not as abundant as in fine-grained marble; dust-like particles and fine-grained flakes	0.5-1.0	Phlogopite, tremolite, actinolite (<10)	Massive to foliated	Fine-grained to medium-grained marble
	Middle and upper almandine amphibolite and hornblende hornfels	>70	Minor fine-grained flakes	1.0-3.0	Phlogopite, biotite, epidote, tremolite, hornblende, diopside, scapolite (<15)	Massive to foliated	Medium-grained marble
	Zones of intense deformation in lower and middle almandine amphibolite, upper almandine amphibolite, and hornblende hornfels	>80	Rare fine-grained to medium-grained flakes	Generally 3.0-5.0	Phlogopite, biotite, epidote, tremolite, hornblende, diopside, scapolite (<10)	Massive to poorly foliated	Coarse-grained marble
Sandy and silty limestone and dolostone (clastic, non-carbonate minerals between 10 and 40 percent)	Middle and upper greenschist	>50	Same as fine-grained marble	<0.5	Phlogopite, tremolite, chlorite (10-40)	Massive to foliated	Fine-grained phlogopitic and tremolitic marble
	Upper greenschist, lower almandine amphibolite, and albite-epidote hornfels	>40	Same as fine-grained to medium-grained marble	0.5-1.0	Phlogopite, tremolite, actinolite, epidote (10-50)	Massive to foliated	Fine-grained to medium-grained phlogopitic and tremolitic marble
	Middle and upper almandine amphibolite and hornblende hornfels	>20	Rare fine-grained to medium-grained flakes	Generally 1.0-4.0	Phlogopite, biotite, tremolite, hornblende, diopside, scapolite, epidote, vesuvianite (10-60)	Granoblastic and foliated	Calc-silicate granofels[1] (granoblastic); calc-silicate gneiss (foliated)
	Hornblende hornfels	Variable (rarely absent)	Absent	0.5-1.0	Diopside, hornblende, biotite, epidote, scapolite, vesuvianite (60-85; at least 10 percent diopside present and hornblende is minor)	Granoblastic; sharply defined compositional layering made of alternating quartzo-feldspathic and diopside-hornblende layers	Layered diopside hornfels
Quartz-rich dolostone	Almandine amphibolite and hornblende hornfels	0-20	Generally absent	Variable	Mainly tremolite (>75)	Massive with coarse-grained tremolite porphyroblasts	Tremolite rock
	Upper almandine amphibolite and hornblende hornfels	0-20	Generally absent	Variable	Mainly diopside (>75)	Granoblastic	Diopside granofels
B. CONTACT METAMORPHISM WITH SILICA, ALUMINA, AND POTASSIA METASOMATISM							
Impure limestone and dolostone (clastic, non-carbonate minerals less than 50 percent)	Hornblende hornfels	Variable (generally <15)	Generally absent	Variable	Rock composed mainly of Ca-Al, Ca-Mg, and Mg silicates; potassic feldspar, and quartz. Garnet, Fe-Al, and Ca-Fe-Mg silicates rare. Concentrations of iron-titanium oxide minerals absent.	Either granoblastic or massive and porphyroblastic	Felsic tactite
Quartz-rich dolostone	Hornblende hornfels	Variable	Generally absent	Variable	Abundant talc, minor amphibole	Massive	Talc rock
C. CONTACT METAMORPHISM WITH SILICA, ALUMINA, AND IRON METASOMATISM							
Impure limestone and dolostone (clastic, non-carbonate minerals less than 50 percent)	Hornblende hornfels	Variable (generally <15)	Generally absent	Variable	Rock composed mainly of Ca-Fe-Mg and Fe-Al silicates; Ca-Al and Ca-Mg silicates minor. Andraditic garnet common. Concentrations of iron-titanium oxide minerals present.	Either granoblastic or massive and porphyroblastic	Mafic tactite

[1] Some calc-silicate granofels and gneiss in contact metamorphic aureoles may have undergone metasomatism; some formed by regional metamorphism may have undergone *in situ* metasomatism.

siliceous metasediments are assumed to have been derived from a detritai clay-sized matrix, then these rocks can be subdivided according to Pettijohn's (1957) classification of sandstones. Most of the sandy metasediments were derived from feldspathic greywacke, but a few were derived from arkose and subarkose. Near intrusions, the clastic siliceous metasediments underwent contact metamorphism and were converted partly to micaceous quartzo-feldspathic hornfels.

Carbonate metasediments, which were derived from impure limestone and dolostone, are composed mainly of carbonate and calcium and magnesium silicate minerals. Regional and contact metamorphism of variable intensity and primary mineralogical and chemical variations were major factors in producing the complex lithology of the carbonate metasediments which are subdivided as shown in Table 3. Clastic, non-carbonate minerals of the primary rock types were largely destroyed by metamorphism. In the marbles, clastic quartz and feldspar grains are present in greenschist and lower almandine amphibolite facies varieties, and calcite and graphite increase in grain size[1] with increased grade of regional metamorphism. In general, the grain size of dolomite does not increase as much as does that of calcite, and the abundance of graphite decreases with increased metamorphic grade. Minor marble tectonic breccia formed by local flowage within marble which contained thin, sandy and silty, clastic metasedimentary layers, is found throughout the area.

Rocks of the calcareous metasandstone and metasiltstone groups were derived from calcareous feldspathic greywacke containing about 30 to 50 percent carbonate and from sandy and silty limestone and dolostone which contained a high proportion (perhaps 40 to 50 percent) of clastic, non-carbonate minerals. In the field, all gradations exist between rocks of this group and the clastic siliceous and carbonate metasediments, and, as shown in Table 4, the lithology of the group varies according to the grade of metamorphism. Except for the calcareous feldspathic metagreywacke, rocks of the group are characterized by more than 10 percent amphibole and less than 45 percent carbonate. Para-amphibolite closely resembles foliated amphibolite of volcanic origin, and it is possible that some rocks mapped as para-amphibolite are metavolcanics.

LITHOLOGY

Clastic Siliceous Metasediments

Clastic siliceous metasediments consist mainly of foliated feldspathic metagreywacke which on an unweathered surface is light to dark-grey and on a weathered surface, either light-grey, or light-brown to rusty-brown; brown shades are caused by the oxidation of iron oxide and sulphide minerals. Middle greenschist facies varieties rarely contain porphyroblasts; in upper greenschist facies

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[1] In this report, fine-, medium-, and coarse-grained are given special definitions as shown in Table 3, *only* when applied to the grain size of calcite in the carbonate metasediments. In all other references to grain size, fine-grained is less than 1.0 millimetre, medium-grained is between 1.0 millimetre and 5.0 millimetres, and coarse-grained is greater than 5.0 millimetres.

Table 4 GENERALIZED SUBDIVISION OF CALCAREOUS METASANDSTONE AND METASILTSTONE GROUP

PRIMARY ROCK TYPE	METAMORPHIC FACIES	AMPHIBOLE (VOLUME PERCENT)	CARBONATE CONTENT (VOLUME PERCENT)	TEXTURE	ROCK NAME
Calcareous feldspathic metagreywacke with 30 to 50 percent carbonate, and sandy and silty limestone and dolostone rich in clastic, non-carbonate minerals	A. REGIONAL METAMORPHISM				
	Middle greenschist	Actinolite (<10)	30-50	Massive to foliated; rare porphyroblastic aggregates of chlorite and actinolite	Calcareous feldspathic metagreywacke
	Middle and upper greenschist	Actinolite (10-40)	<10-40 (rarely absent)	Spherical, medium- to coarse-grained porphyroblastic aggregates of chlorite and actinolite	Porphyroblastic actinolite metasediments
	Almandine amphibolite	Hornblende (10-40)	0-25	Spherical, medium- to coarse-grained hornblende aggregates and coarse-grained, feathery, hornblende porphyroblasts	Porphyroblastic hornblende metasediments
	Almandine amphibolite	Hornblende (>40)	0-10	Equigranular and foliated	Para-amphibolite (possibly derived in part from volcanics)
	B. CONTACT METAMORPHISM				
	Albite-epidote hornfels	Tremolite-actinolite (15-45)	5-20	Medium-grained amphibole porphyroblasts in a fine-grained, granular matrix; sharply defined compositional layering consisting of alternating quartzo-feldspathic and amphibole-rich layers common	Layered amphibole hornfels
	Hornblende hornfels	Hornblende (15-45) Minor diopside common	0-10	Same as above	Layered amphibole hornfels

varieties, biotite porphyroblasts are common and white mica and garnet porphyroblasts are rare. Lower and middle almandine amphibolite facies varieties, which are characterized by coarse-grained muscovite porphyroblasts, commonly contain medium- to coarse-grained porphyroblasts of garnet and biotite.

The metagreywacke exhibits rhythmic bedding of two major types: 1) graded bedding in which sandy detrital material below grades upward to silty above, and this is succeeded along a sharp contact by the sandy base of the next

Table 5 MODAL AND CHEMICAL COMPOSITIONS OF METASEDIMENTS

	CALCAREOUS METASANDSTONE AND METASILTSTONE				CARBONATE-POOR METASEDIMENTS				
SAMPLE NUMBER	1	2	3	4	5	6	7	8	9
				MODES (VOLUME PERCENT)					
Quartz	20.0	17.5	11.0	7.7	26.7	28.0	35.0	73.0	....
Plagioclase	15.0	19.8	15.1	37.0	15.6	25.2	17.5	3.6	....
Percent An	2	2-12	2-11	8-18		2	5	2	....
Biotite	17.3	11.1	14.9	....	47.4	20.6	5.8	15.2	....
Amphibole	2.5	27.1	14.5	43.1	6.6	....	....	....	....
Carbonate	42.6	15.5	40.0	0.5	1.7	15.9	27.6	5.6	....
Chlorite	0.5	4.0	1.8	....	....	6.8	Trace	....	....
White Mica	....	....	....	....	....	0.2	11.7	1.4	....
Opaque Minerals	2.1	4.9	2.6	9.7	1.9	1.4	2.4	1.2	....
Apatite	Trace	0.1	0.1	2.0	Trace	....	Trace	Trace	....
Others	Trace	....	....	Trace	0.1	1.9	....	....	....
Totals	100.0	100.0	100.00	100.0	100.0	100.0	100.0	100.0	
				CHEMICAL ANALYSES (WEIGHT PERCENT)					
SiO_2	37.29	47.85	....	....	58.61	....	....	....	61.59
Al_2O_3	9.34	12.77	....	....	13.81	....	....	....	19.47
Fe_2O_3	0.34	0.81	....	....	1.41	....	....	....	1.96
FeO	3.96	6.29	....	....	8.53	....	....	....	3.07
MgO	3.20	3.67	....	....	3.50	....	....	....	1.09
CaO	23.26	13.85	....	....	3.55	....	....	....	2.60
Na_2O	2.09	2.72	....	....	3.22	....	....	....	3.32
K_2O	1.17	1.17	....	....	3.34	....	....	....	2.58
H_2O+	0.90	1.02	....	....	1.25	....	....	....	1.48*
H_2O-	0.12	0.17	....	....	0.17	....	....	....	
CO_2	17.86	8.39	....	....	0.93	....	....	....	0.06
TiO_2	0.51	0.86	....	....	1.00	....	....	....	....
P_2O_5	0.18	0.24	....	....	0.40	....	....	....	....
MnO	0.09	0.10	....	....	0.14	....	....	....	....
Totals	100.31	99.91			99.86				97.22

*In sample 9, H_2O+ and H_2O- are combined.

SAMPLES:

1–Calcareous feldspathic metagreywacke, middle greenschist facies, lot 12, east of Hastings Road, Tudor Township. Chemical analysis by J. Muysson, McMaster University.

2–Porphyroblastic actinolite metasediment, upper greenschist facies, lot 18, concession II, Limerick Township. Chemical analysis by J. Muysson, McMaster University.

3–Porphyroblastic actinolite metasediment, upper greenschist facies, lot 21, concession IV, Limerick Township.

4–Para-amphibolite, lower almandine amphibolite facies, lot 5, concession VII, Limerick Township.

5–Silty upper part of feldspathic metagreywacke graded bed, lower almandine amphibolite facies, lot 23, concession IV, Limerick Township. Chemical analysis by J. Muysson, McMaster University.

6–Feldspathic metagreywacke, middle greenschist facies, lot 24, concession XVIII, Tudor Township.

7–Feldspathic metagreywacke, middle greenschist facies, lot 93, east of Hastings Road, Tudor Township.

8–Feldspathic metagreywacke, middle greenschist facies, lot 6, east of Hastings Road, Tudor Township.

9–Composite sample composed of 15 chips of feldspathic metagreywacke matrix of polymictic metaconglomerate near village of Gilmour, Tudor Township. From Miller and Knight (1913, p. 87).

graded bed; and 2) rhythmic alternations in which beds composed of medium to fine sand alternate with beds composed of fine sand and coarse silt, and in which the sandy beds are generally much thicker than the silty beds. Although grain gradation in the rhythmic alternations cannot be detected megascopically, it can be detected rarely microscopically. Individual beds range in thickness from ½ inch to rarely over 3 feet and rhythmic alternations are more abundant than graded bedding which is best developed in southern Tudor Township. Crossbedding, which was found only in the rhythmic alternations, and intraformational metaconglomerate, which was found in association with only graded beds, are rare. Channelling is found both at the base of overlying graded beds and within the rhythmic alternations.

Chlorite, which is found only in greenschist facies metagreywacke, and micas form as much as 60 percent of the fine-grained upper parts of graded beds and of some silty beds in the rhythmic alternations; elsewhere these minerals do not exceed 30 percent of the rock. Near units of calcareous metasandstone and metasiltstone and of carbonate metasediments, a few amphibole porphyroblasts, impure marble layers, and lens-like carbonate aggregates are common in the metagreywacke. Three modes which show the range in composition of middle greenschist facies metagreywacke, and a mode of the silty upper part of a graded bed are given in Table 5 (columns 5 to 8). The quartz content of the feldspathic metagreywacke varies greatly; most rocks contain between 25 and 60 percent quartz. Potassic feldspar is rare in greenschist facies metagreywacke but is present as a metamorphic mineral in the silty parts of rhythmic beds in almandine amphibolite facies metagreywacke.

Meta-arkose forms distinct layers interbedded with feldspathic metagreywacke in the vicinity of Steenburg Lake, in the vicinity of a thin, mafic metavolcanic flow south of Steenburg Lake in lots 24 and 25, concession XVIII, Tudor Township, and near the village of St. Ola in lots 8 and 9, concession I, and lots 7 and 8, concession II, Limerick Township. Polymictic metaconglomerate, and rare amphibole-rich rocks that may be of volcanic origin are interbedded with the St. Ola meta-arkose. The meta-arkose is medium- to very thick-bedded and is composed of fine- to medium-grained quartz, albite, carbonate, and rare potassic feldspar, and less than 15 percent combined chlorite, white mica, and biotite. Rare metasubarkose, containing about 85 percent quartz, and less than 15 percent combined white mica, biotite, and albite, is interbedded with feldspathic metagreywacke in southern Tudor Township (Photo 6).

Polymictic metaconglomerate is exposed in the vicinity of St. Ola in southern Limerick Township and between the Wadsworth and Beaver Creek intrusions in northern Tudor Township. Rhythmic bedding is characteristic of the metaconglomerate; commonly a bed of cobble and pebble conglomerate at the base grades upward to medium-grained sandstone at the top (Photo 7); rarely, rhythmic alternations are present in which very thick-bedded, cobble and pebble conglomerate beds alternate with medium- to thick-bedded, medium- to coarse-grained sandstone beds. Channelling commonly is present at the base of the next bed in both graded beds and rhythmically alternating beds, but crossbedding is rare. Feldspathic metagreywacke forms the matrix of the metaconglomerate and the sandy parts of the rhythmically bedded metaconglomerate sequences. Pebbles and cobbles in the metaconglomerate consist of coarse-grained quartz,

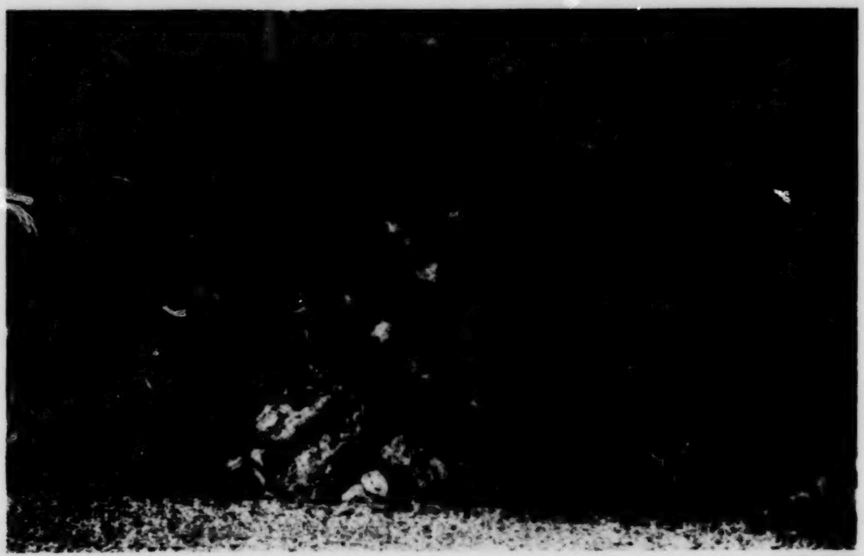

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Photo 6–Very thick-bedded metasubarkose interbedded with feldspathic metagreywacke (below hammer handle). Note well developed jointing both parallel and at a slight angle to the hammer handle. Roadside rock cut, Highway 62, lot 6, east of Hastings Road, Tudor Township.

ODM7501

Photo 7–Rhythmically bedded polymictic metaconglomerate (pitted, irregular surface) and feldspathic metagreywacke. Metaconglomerate at the base of graded beds grades upward (towards hammer) into metagreywacke at the top. Lot 12, concession XVIII, Tudor Township.

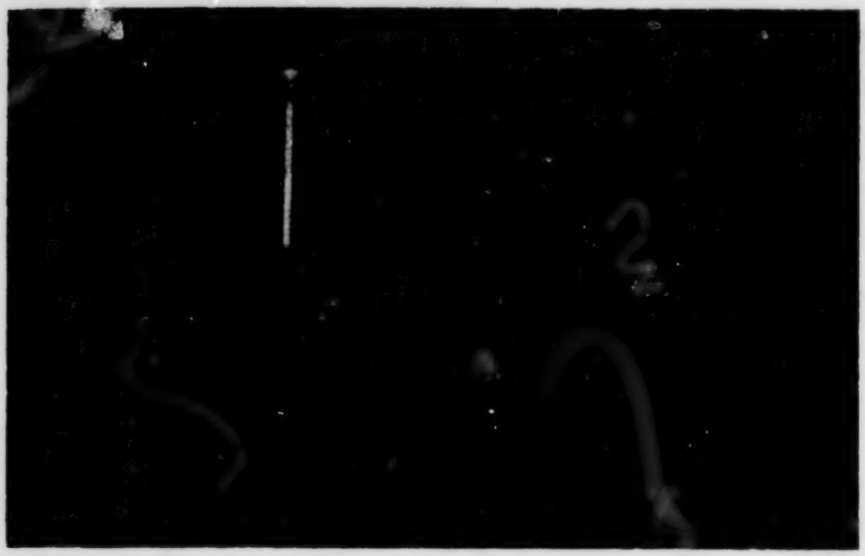

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Photo 8–Interbedded, fine- to medium-grained marble (above the eraser and under the point of the pencil) and porphyroblastic actinolite metasediments, lot 16, concession II, Limerick Township.

fine-grained granular quartz, feldspathic metagreywacke, dolomitic and calcitic marble, felsic metavolcanics, and mica-rich metasiltstone that closely resembles the upper silty part of feldspathic metagreywacke graded beds; boulders are rare, the average size of the coarse detritus, which is formed and either subangular or subrounded, is about two inches, and felsic metavolcanic fragments are less abundant than other fragment types. Near intrusions in northern Tudor Township, the metaconglomerate is either sheared almost beyond recognition, or hornfelsed.

Calcareous Metasandstone and Metasiltstone

Rocks of the calcareous metasandstone and metasiltstone group are either interbedded with carbonate metasediments, or form a transition facies between clastic siliceous and carbonate metasedimentary sequences. Middle greenschist facies rocks of the group in Tudor Township consist mainly of complexly interbedded calcareous feldspathic metagreywacke and fine-grained phlogopitic and tremolitic marble containing as much as 50 percent combined phlogopite, tremolite, quartz, feldspar, biotite, and chlorite. With increasing metamorphic grade, the carbonate, biotite, chlorite, and quartz contents of these rocks decrease, the amphibole and plagioclase contents increase, plagioclase becomes more calcic in composition, and amphibole changes from actinolite-tremolite in the greenschist facies to hornblende in the almandine amphibolite facies. Upper greenschist facies rocks of the group consist mainly of porphyroblastic actinolite metasediments (Photo 8), and almandine amphibolite facies rocks of the group consist of porphyroblastic hornblende metasediments and of para-amphibolite. Modes of a calcareous feldspathic metagreywacke, two porphyroblastic actinolite metasediments, and a para-amphibolite are listed in Table 5.

Porphyroblastic actinolite and hornblende metasediments are foliated, grey to dark-green rocks; the colour depends on the abundance of amphibole. Except for numerous, generally non-oriented, medium- to coarse-grained amphibole porphyroblasts, many of these rocks closely resemble feldspathic metagreywacke; amphibole is either concentrated in crude layers, or disseminated throughout the rock. Where hornblende forms more than about 40 percent of the rock, para-amphibolite was formed locally in porphyroblastic hornblende metasediment beds; the hornblende is generally equigranular and porphyroblasts are rare. Bedding, which is generally well preserved in middle greenschist facies rocks of the group, is partly obscured by the growth of amphibole porphyroblasts in the higher grade rocks of the group.

In contact metamorphic aureoles, calcareous feldspathic metagreywacke and porphyroblastic actinolite and hornblende metasediments were converted to fine-grained, dark-green to light-greenish-grey, layered amphibole hornfels which consists mainly of amphibole, plagioclase, quartz, carbonate, epidote, and biotite. Although this rock is generally granoblastic, amphibole porphyroblasts are rarely aligned in a granular matrix. Hornblende hornfels varieties differ from albite-epidote hornfels varieties by containing: 1) zoned oligoclase-labradorite rather than zoned albite; 2) hornblende rather than actinolite-tremolite; 3) less epidote; and 4) minor amounts of diopside and scapolite.

Carbonate Metasediments

In Tudor Township and in the southeast corner of Limerick Township, most of the carbonate metasediments were metamorphosed to the middle greenschist facies and consist of intimately interbedded, poorly foliated, grey, dark-grey, or bluish-grey, fine-grained marble and fine-grained phlogopitic and tremolitic marble. Graphite, quartz, phlogopite, pyrite, feldspar, and tremolite are the main impurities in these marbles. Fine- to medium-grained, phlogopite and tremolite porphyroblasts are rare in the fine-grained marble but form at least 10 percent of the fine-grained phlogopitic and tremolitic marble which also contains numerous, closely spaced, phlogopite- and tremolite-rich partings. Both marbles are generally finely laminated to thin-bedded (Photo 9); medium- to thick-bedded varieties are rare. Bedding is defined by: 1) concentrations of aligned phlogopite and tremolite in even-bedded interbeds only a fraction of an inch thick; 2) concentrations of dust-like graphite particles which produce a dark-coloured marble; and 3) uneven-bedded interbeds less than 2 inches thick consisting of a) calcareous feldspathic metagreywacke, b) calcareous metasiltstone which contains as much as 60 percent combined chlorite, biotite, and white mica, and c) combinations of (a) and (b). On weathered surfaces, the silicate mineral-rich interbeds stand up in relief to produce a ribbed surface. Medium- to coarse-grained, white calcite patches and veinlets, which are generally at an angle to the bedding, are abundant in the marbles (Photo 9), and many of the calcite veins are lens-like and appear to fill extension fractures and joints; rare quartz and quartz-calcite fillings of the extension fractures and joints are found. Fine-grained, euhedral, pyrite

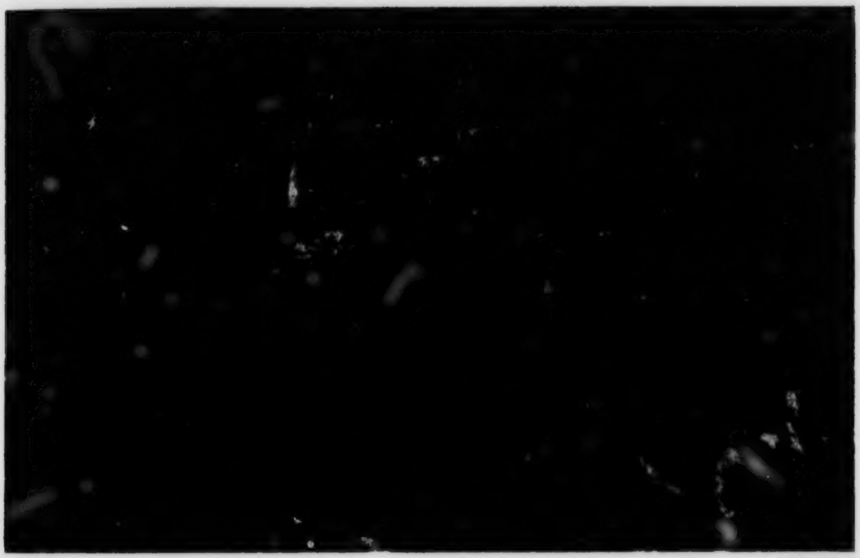

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Photo 9–Typical fine-grained marble containing numerous coarse-grained white calcite patches and veinlets mainly at an angle to the bedding, lot 28, east of Hastings Road, Tudor Township.

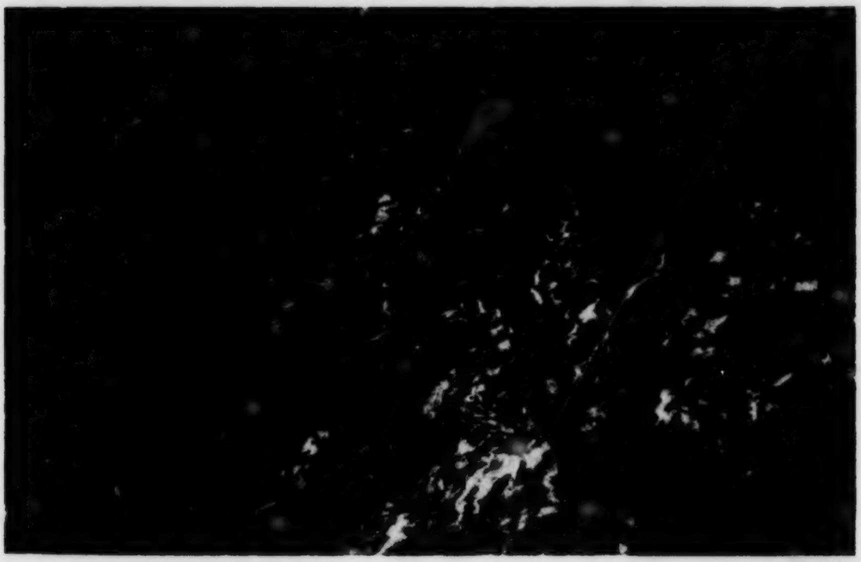

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Photo 10–Typical fine- to medium-grained marble. Note the contorted bedding and also that most of the white calcite patches are subparallel to the bedding. Lot 11, concession II, Limerick Township.

crystals and massive, pyrite streaks are common along the joints and, in places, fine- to medium-grained, euhedral pyrite is disseminated in crude layers parallel to the bedding in the marbles.

In southern, central, and north-central Limerick Township, most of the carbonate metasediments were metamorphosed to the upper greenschist and lower almandine amphibolite facies and consist of fine- to medium-grained marble and fine- to medium-grained phlogopitic and tremolitic marble, both of which show the following differences when compared to the fine-grained marbles (see Table 3):

1. Grain size of calcite, graphite, and porphyroblasts of tremolite and phlogopite is slightly coarser.
2. Graphite is coarser grained and hence the rock has a lighter-grey colour.
3. Because of increased flowage, the bedding is distorted and is less sharply defined (compare Photos 9 and 10).
4. Medium- to coarse-grained patches and veinlets of white calcite are more abundant and generally parallel the bedding.
5. Calcite veinlets commonly show ptygmatic folding.
6. Interbeds of siliceous metasandstones and metasiltstones are generally complexly crumpled and of boudinage form.
7. Detrital plagioclase is recrystallized to zoned albite and to zoned albite-oligoclase.
8. Pyrite is less abundant and pyrrhotite is present rarely.

Within the almandine amphibolite facies terrane in Limerick Township, medium-grained marble and calc-silicate gneiss are common in the zone of complex overfolding in the eastern part of the township and in the northwestern and northeastern parts of the township where the carbonate metasediments were regionally metamorphosed to the middle almandine amphibolite facies. The mineralogy of these rocks is similar to that of the fine- to medium-grained marbles, but where these rocks were metamorphosed to the middle almandine amphibolite facies, minor amounts of hornblende, diopside, scapolite, and epidote are present; biotite is more abundant than phlogopite, and plagioclase is zoned oligoclase-andesine. Relic bedding in the medium-grained marble consists of alternating, gradational, light-grey to white calcite layers and grey to light-grey layers with up to 15 percent combined phlogopite and tremolite, most of the graphite present in the rock, and locally abundant biotite. Light-grey to white calcite layers pinch and swell, are complexly contorted internally, and locally, cut across the phlogopitic and tremolitic layers at a small angle. Discordant calcite veins and lens-like aggregates are rare, and quartz and feldspar impurities are commonly concentrated in spherical clumps and in lens-like aggregates parallel to the bedding. Except for containing more than 15 percent silicate minerals in crudely defined layers which probably mark relic bedding, calc-silicate gneiss is similar to medium-grained marble. In lot 31, concession VIII, Limerick Township, a layer of calc-silicate gneiss as much as 15 feet thick contains about 20 percent coarse-grained scapolite porphyroblasts and abundant biotite; this rock which was found only in this one layer, is well exposed in a roadside rock cut on Highway 620. Rare calc-silicate granofels, which is a granoblastic, medium- to coarse-grained variety of calc-silicate gneiss without mineral layering, is found in the middle almandine amphibolite facies.

In the almandine amphibolite facies terrane of eastern Limerick Township, coarse-grained marble developed near the hinge portion of complex overfolds. In the coarse-grained marble, bedding is generally destroyed, but poorly aligned streaks and patches of medium- to coarse-grained silicate minerals give the rock a poor gneissosity. This clustering of silicate mineral impurities is probably due to metamorphic differentiation during flowage of the marble. In the coarse-grained marble, graphite is either rare or absent and the marble is consequently greyish-white or white, or is various shades of brown due to oxidation of accessory sulphide and iron oxide minerals.

Dolomitic marble is scarce in the map-area, and most of the known occurrences either overlie, or are interbedded with, metavolcanics. In general, the dolomitic marble is confined to well defined beds, and it is more compact and less friable than calcitic marble. In the greenschist facies, dolomitic marble is commonly characterized by a rusty-weathering surface, but in higher, regional, metamorphic grades and in contact metamorphic aureoles, the dolomitic marble is light-brown or white and contains abundant tremolite porphyroblasts. Where quartz-rich dolomitic marble is regionally metamorphosed to the lower and middle almandine amphibolite facies, it is commonly converted to tremolite granofels, a medium- to coarse-grained, granoblastic rock composed of more than 75 percent tremolite.

Contact metamorphism and metasomatism of the carbonate metasediments produced a large variety of mineral assemblages. Where metamorphosed to the albite-epidote hornfels facies, carbonate metasediments that have not undergone metasomatism have essentially the same mineralogy as regionally metamorphosed fine- to medium-grained marbles. Nevertheless, flowage is much more pronounced in these rocks in the contact metamorphic aureoles than in regionally metamorphosed areas. Where metamorphosed to the hornblende hornfels facies, the carbonate metasediments that have not undergone metasomatism consist mainly of medium- and coarse-grained marbles and calc-silicate gneiss and granofels which commonly contain diopside, vesuvianite, and microcline. In the innermost part of aureoles, calc-silicate gneiss and granofels grade into layered diopside hornfels; diopside granofels is found in the innermost part of some mafic intrusion aureoles.

Metasomatized carbonate metasediments, which are confined mainly to the innermost part of contact metamorphic aureoles, are found locally near dikes and sills in the outer part of some aureoles and consist mainly of mafic and felsic tactite. Mafic tactite is found in the aureoles of the Glanmire, Tudor, and Wadsworth intrusions and is most abundant at the southern margin of the Wadsworth intrusion. The general mineralogy of the mafic tactite, which varies greatly, can be summarized as follows:

Major Minerals (greater than 10%)

Clinopyroxene (an iron-rich member of the diopside-hedenbergite series), andraditic garnet, epidote (commonly pistacite), calcite, plagioclase (zoned oligoclase-andesine).

Minor Minerals (less than 10%)

Amphibole (commonly dark-green hornblende), biotite (iron-rich), quartz, microcline, magnetite, specular hematite, sphene, apatite, vesuvianite, pyrite, pyrrhotite, chalcopyrite.

Felsic tactite, which is much less abundant than mafic tactite, contains only rare iron-rich silicate minerals and is most common at the borders of granitic, syenitic, and pegmatitic dikes and sills in the contact metamorphic aureoles. Most felsic tactite contains abundant epidote (commonly clinozoisite) amphibole, and quartz; calcite, microcline, and plagioclase are generally present. Some common felsic tactites are diopside-microcline hornfels, plagioclase-scapolite-hornblende hornfels, and clinozoisite-microcline-quartz-diopside-plagioclase hornfels.

Eighteen chemical analyses of marbles have been reported from various parts of the map-area by Miller and Knight (1913), by Gouge (1938), by Chayes (1942), and by Laakso (1961). Sixteen of the analyses have CaO:MgO ratios greater than 10.5 (calcitic limestone containing less than 10 percent dolomite), one analysis has a CaO:MgO ratio of 8.9 (dolomitic limestone containing less than 50 percent dolomite), and one has a CaO:MgO ratio of 1.6 (dolostone containing more than 50 percent dolomite). In addition, Laakso (1961) has analysed 20 specimens that were collected across the strike of a typical fine-grained marble outcrop exposed on the Tudor/Lake township boundary where the Hastings Road crosses Beaver Creek; 11 analyses are calcitic limestone and the rest are dolomitic limestone; no dolostone was found.

Stratigraphy

GENERAL

Several features of the metavolcanics and metasediments, such as complex folding and faulting, regional variations in metamorphic grade, and numerous facies changes accomplished either by complex intertonguing of relatively pure lithofacies, or by lateral gradation of one lithofacies into another, seriously hinder a reconstruction of the stratigraphic section. Nevertheless, the following features of these rocks allow a tentative reconstruction of the stratigraphic section: 1) preserved, primary megastructures indicative of top directions; 2) fracture cleavage; 3) relatively continuous lithologic units; and 4) continuity of lithologic units with major folds. Stratigraphic units recognized in the area and their distributions are shown in Figure 4 (Chart A, back pocket).

The metavolcanic-metasedimentary sequence can be divided into two main parts: 1) a metavolcanic-rich group consisting of the Tudor metavolcanics, the Oak Lake formation, the Vansickle formation, the Turriff metavolcanics, and the Burnt Lake formation; and 2) the Dungannon formation rich in carbonate metasediments. The Dungannon formation, the upper part of which overlies the metavolcanic group, interfingers with, and is partly equivalent in age to, all the formations of the metavolcanic group that overlie the Tudor metavolcanics. Pillow lavas are common in the mafic metavolcanics of the sequence, and, locally, thin marble units are interbedded with the metavolcanics. Evidently, the metavolcanics were extruded into a marine environment in which was deposited the carbonate metasediments of the Dungannon formation. The oldest metavolcanics, the Tudor metavolcanics, are predominantly basaltic, whereas the youngest metavolcanics are predominantly felsic and andesitic; all the metavolcanics were probably derived from a common magma that underwent continuous differentiation from mafic to felsic. Metagreywacke and metaconglomerate units present in the area are confined either to the metavolcanic group, or to those parts of the Dungannon formation that interfinger with the metavolcanic group. Although most of these metsediments were derived from nearby highlands of dacitic and felsic volcanic rocks, the presence locally of well-sorted, quartz-rich metasandstones suggests that some material was eroded from a sedimentary rock terrain, possibly either an older, more distal part of the geosynclinal tract, or basement rocks. The Turriff metavolcanics and the Burnt Lake formation appear to represent local renewal of volcanic activity that followed quiescent periods of sedimentation. Although the base is unknown, the metavolcanic-metasedimentary sequence is Proterozoic in age, and the present exposures of the sequence represent a maximum thickness of about 27,000 feet.

TUDOR METAVOLCANICS

The Tudor metavolcanic formation is composed mainly of mafic metavolcanics and contains some felsic flow and pyroclastic rocks, and, rarely, carbonate metasediments and iron formation. This formation, whose base is unknown, forms a regional domical mass exposed over more than 600 square miles in the central and eastern parts of the Bancroft–Madoc area (Lumbers 1964; 1967a). Throughout most of the map-area, the Tudor metavolcanics are overlain by the felsic metavolcanic-rich Oak Lake formation, but, locally, carbonate metasediments of the Dungannon formation abruptly overlie the Tudor metavolcanics without angular unconformity. Between the Beaver Creek and Lingham Lake Complexes in Tudor Township, a steeply dipping, monoclinal section of the Tudor metavolcanics is about 18,000 feet thick.

Isotopic studies of uranium-lead systems in zircons from two metarhyolite specimens collected from the felsic metavolcanic units exposed in the north half of lot 5, concession XIII, and lot 6, concession XVI, Tudor Township, show that these rocks share an indicated age of 1,310 ± 15 million years (Silver and Lumbers 1966). The most southerly felsic metavolcanic unit is about 16,900 feet below the top of the Tudor metavolcanics, and the age obtained from both units may represent a mean age for the formation.

OAK LAKE FORMATION

Within the map-area, the Oak Lake formation, which generally overlies the Tudor metavolcanics throughout the central and western parts of the Bancroft–Madoc area (Lumbers 1967a), consists mainly of amphibole-poor mafic metavolcanics in the lower part and felsic metavolcanics in the upper part, and it interfingers with the underlying Tudor metavolcanics; the boundary between the two formations is arbitrarily placed where felsic and amphibole-poor mafic metavolcanics compose more than 50 percent of the sequence. Commonly, the formation, which ranges in thickness from 0 to about 1,300 feet, is abruptly overlain without angular unconformity by the Dungannon formation, but in lot 9, concession XVIII, and in lot 12, concession XVII, Tudor Township, the upper part of the formation interfingers with the Dungannon formation.

VANSICKLE FORMATION

The Vansickle formation, which generally interfingers with the underlying Oak Lake formation, can be traced from southeastern Methuen Township through western Lake Township, to southeastern Wollaston Township and northeastern Lake Township (Laakso 1968). In the map-area, the formation, which is composed mainly of clastic siliceous metasediments, calcareous metasandstone and metasiltstone, and minor metavolcanics, is exposed largely in western Limerick Township, and northwestern and southern Tudor Township and is separated from the underlying Oak Lake formation and Tudor metavolcanics by tongues of the lower part of the Dungannon formation. The upper part of the Vansickle formation is overlain by the Dungannon formation, but, locally the formation is overlain by the Turriff metavolcanics and the Burnt Lake formation. The Grassy Lake quartzite and part of the Turriff rusty schist, which extend southward from Dungannon into northern Limerick Township, and which were defined by Hewitt and James (1955) as members of the Dungannon formation, are assigned by the author to the Vansickle formation. In southwestern Limerick Township, the formation has a minimum thickness of about 6,000 feet; elsewhere in the area, the exposed thickness is much less.

TURRIFF METAVOLCANICS

The Turriff metavolcanic formation consists of felsic and mafic metavolcanics and iron formation exposed on the east and west flanks of the complex Murphy Corners Anticline. This formation, which interfingers with, and, locally overlies, the upper part of the Vansickle formation, ranges in thickness from 0 to about 4,700 feet. In the west limb of the Murphy Corners Anticline, the formation was intruded by the Thanet Complex.

BURNT LAKE FORMATION

Mafic metavolcanics and minor clastic siliceous metasediments exposed south of Brett Lake in northwestern Tudor Township and in the Robinson Lake Syncline in west-central Limerick Township are part of the Burnt Lake formation (Laakso 1968). This formation is exposed mainly in Lake and Wollaston Townships west of the map-area where it interfingers with, and overlies, the upper part of the Vansickle formation and the lower part of the Dungannon formation, and is overlain by the upper part of the Dungannon formation. In the map-area, the Burnt Lake formation forms tongues in the Dungannon formation and, locally, overlies the upper part of the Vansickle formation.

DUNGANNON FORMATION

Most of the carbonate metasediments in the map-area are assigned to the Dungannon formation which can be traced from the type area in Dungannon and Mayo Townships (Hewitt and James 1955) through the map-area into townships west and south of the map-area. Within the map-area, particularly in eastern Limerick Township, thin members composed of clastic siliceous metasediments and calcareous metasandstone and metasiltstone are interbedded with the carbonate metasediments of the formation. The lower part of the formation overlies the Oak Lake formation and the Tudor metavolcanics, and the upper part of the formation, which comprises the youngest rocks of the metavolcanic-metasedimentary sequence in the map-area, overlies the Vansickle formation, the Turriff metavolcanics, and the Burnt Lake formation. The maximum exposed thickness of the Dungannon formation in the map-area is probably less than 8,000 feet.

INTRUSIVE ROCKS

Sodic Granitic and Syenitic Rocks

GENERAL

Sodic granitic and syenitic rocks, which are characterized by abundant sodic plagioclase, by potassic feldspar to total feldspar ratios less than one-half, and by high soda to potassia ratios, consist of trondhjemite, granodiorite, and various types of albite granite and albite syenite. The albite granites and syenites, which are among the oldest intrusive rocks in the area, form 14 minor stocks in northern Tudor Township and southern Limerick Township and most of the Glanmire and Beaver Creek Complexes in northwestern Tudor Township. The Wendsley Lake intrusion in northern Limerick Township is composed mainly of recrystallized albite granite. Four trondhjemite stocks are present in the area: the Grimsthorpe and Wadsworth stocks in Tudor Township, and two minor stocks in northern Limerick Township. Minor trondhjemite is also found in the Glanmire and Beaver Creek Complexes and is a late phase in the Tudor, Jocko Lake, and Lingham Lake stocks. Granodiorite is found sparingly in the Glanmire Complex, in the trondhjemite stocks in northern Limerick Township, and with trondhjemite in the Tudor, Jocko Lake, and Lingham Lake intrusions.

Numerous features of the albite granite and syenite stocks, such as their discordant nature, their composite character, incorporation in place of country rocks, roof pendants, scarcity of foliation, porphyritic character of the felsic rocks, lack of well developed pegmatite dikes, local abundance of granophyre, local fine-grained border facies, sharp contacts with the country rocks, and the presence of various types of breccias, are most typical of epizonal intrusions emplaced at shallow depths within the earth's crust. In contrast to the albite granite and syenite stocks, the trondhjemite stocks, which probably were emplaced at greater depths, lack fine-grained phases, they show less variation in mineralogy, they are foliated locally, and most contain pegmatite dikes. All the stocks have contact metamorphic aureoles, but aureoles of albite granite and syenite stocks in the almandine amphibolite facies terrane in Limerick Township were largely destroyed by the regional metamorphism.

Table 6 | MODAL AND CHEMICAL COMPOSITIONS OF SODIC GRANITIC AND SODIC SYENITIC ROCKS

SAMPLE NUMBER	1	2	3	4	5	6	7	8
				MODES (VOLUME PERCENT)				
Plagioclase	58.9	73.1	40.4	68.5	30.1	49.0	67.3	54.5
Percent An	7	2	5-11	5	5	12	4-17	12
Quartz	19.2	21.1	22.6	3.9	7.9	27.6	9.1	26.4
Potassic Feldspar	....	....	11.7	....	....	17.7	1.1	0.8
Biotite	9.0	0.3	7.7	4.6	11.2	3.1	....	13.0
Amphibole	0.7	....	....	7.7	26.7	....	19.1	....
Carbonate	0.9	3.0	1.5	3.3	Trace	....	Trace	2.0
Muscovite	1.4	0.9	16.1	Trace	....	1.6	....	Trace
Chlorite	4.1	0.4	....	3.8	4.9	....	....	0.4
Epidote	0.5	....	....	0.9	6.8	0.8	2.7	0.6
Apatite	1.1	Trace	Trace	0.9	Trace	Trace	0.2	0.4
Opaque Minerals	4.2	1.0	Trace	6.4	12.4	0.1	0.2	0.8
Others	Trace	0.2	Trace	Trace	....	0.1	0.3	1.1
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
				CHEMICAL ANALYSES (WEIGHT PERCENT)*				
SiO_2	63.75	69.94	....	60.15	....	....	....	65.04
Al_2O_3	16.92	16.26	....	16.81	....	....	....	16.91
Fe_2O_3	2.80	1.12	....	3.56	....	....	....	1.99
FeO	2.64	0.57	....	2.29	....	....	....	2.54
MgO	1.73	0.55	....	2.36	....	....	....	1.95
CaO	1.74	0.66	....	3.00	....	....	....	2.35
Na_2O	6.67	8.20	....	8.28	....	....	....	5.01
K_2O	1.74	0.43	....	0.58	....	....	....	2.16
H_2O+	0.93	0.18	....	0.90	....	....	....	0.81
H_2O-	0.07	0.08	....	0.06	....	....	....	0.07
CO_2**	0.24	0.76	....	0.52	....	....	....	0.38
TiO_2	0.57	0.28	....	1.01	....	....	....	0.54
P_2O_5	0.38	0.04	....	0.27	....	....	....	0.13
MnO	0.03	0.01	....	0.02	....	....	....	0.02
Cr_2O_3	Trace	Trace	....	Trace	....	....	....	Trace
V_2O_3	Trace	Trace	....	Trace	....	....	....	Trace
Totals	100.21	99.08		99.81				99.90

*Chemical analyses by Laboratory Branch, Ontario Department of Mines.

**Calculated from loss on ignition.

SAMPLES:

1–Albite granite. Average of seven modes from the Beaver Creek Complex; chemical analysis made from a composite sample composed of equal amounts of the same seven specimens used to determine the average mode.

2–Fine-grained albite granite. Average of eight modes from the Beaver Creek Complex; chemical analysis made from a composite sample composed of equal amounts of the same eight specimens used to determine the average mode.

3–Sodic granite. Specimen No. 62-L-236, from Wendsley Lake Albite Granite, lot 18, concession XIII, Limerick Township.

4–Albite syenite. Average of 12 modes from the Beaver Creek Complex; chemical analysis made from a composite sample composed of equal amounts of the same 12 specimens used to determine the average mode.

5–Amphibole-rich albite syenite. Specimen No. 61-L-196, from Beaver Creek Complex, lot 21, concession XVII, Tudor Township.

6–Granodiorite. Average of five modes from the Glanmire Complex.

7–Contaminated trondhjemite. Specimen No. 61-L-103, from Wadsworth Trondhjemite, lot 7, concession XVIII, Tudor Township.

8–Trondhjemite. Average of 12 modes from Wadsworth Trondhjemite; chemical analysis made from a composite sample composed of equal amounts of the same 12 specimens used to determine the average mode.

Modal and chemical analyses of the most abundant rock types of the sodic granitic and syenitic group are given in Table 6. The abundance of the constituent minerals of individual rock types varies greatly in the albite granite and syenite stocks, but varies only slightly in the trondhjemite stocks.

Fine-grained albite granite and syenite, which are similar in appearance, are massive, equigranular to porphyritic, leucocratic rocks which weather white to pink and are light-grey to pale-pink on unweathered surfaces. Some varieties which contain abundant, fine- to medium-grained pyrite crystals are rusty on weathered surfaces due to oxidation of pyrite. Both rocks contain albite phenocrysts, and some albite granite contains rare, medium-grained, quartz phenocrysts. Within the greenschist facies terrane, these rocks are commonly mylonitized; quartz is strained and albite laths are bent, fractured, and converted into chessboard albite. By a gradual increase in the abundance of medium-grained phenocrysts, both rocks commonly grade into medium-grained varieties.

Medium-grained albite granite is a massive, equigranular to porphyritic rock which weathers pale-green, light-grey, or pink; greenish shades are due to epidote and chlorite. Phenocrysts of albite and quartz as much as 5 millimetres across and granophyric intergrowths of quartz and albite are common. Medium-grained albite syenite is similar to the albite granite except quartz grains are rarely visible, and some varieties contain amphibole. In the Beaver Creek Complex, amphibole-rich albite syenite, which contains 15 to 85 percent medium- to coarse-grained amphibole and numerous, hornfelsed, carbonate metasedimentary inclusions, was developed in consequence of contamination by carbonate metasediments; locally, this rock grades into diorite containing zoned albite-oligoclase.

Within the almandine amphibolite facies terrane, the albite granites and syenites were recrystallized by the regional metamorphism as suggested by the following features: 1) small patches of unrecrystallized rock in the recrystallized rock; 2) in recrystallized portions of the rocks, plagioclase is generally reversely zoned albite-oligoclase granules and porphyroblasts; and 3) sieved, medium- to coarse-grained muscovite porphyroblasts are found only in recrystallized portions of the rocks. In the Wendsley Lake intrusion, recrystallization of the albite granite produced sodic granite which contains as much as 12 percent potassic feldspar associated mainly with plagioclase and biotite porphyroblasts. In places within this intrusion, particularly near the margins, regional metamorphism of the albite granite resulted in the formation of gneisses in which compositional layering is caused by the parallel orientation of: 1) crude biotite layers less than 1 millimetre thick; 2) coarse-grained, lens-like, biotite aggregates; 3) medium-grained muscovite porphyroblasts; and 4) medium-grained, zoned albite-oligoclase porphyroblasts.

Trondhjemite and granodiorite are medium-grained, massive to foliated, grey to pink-weathering rocks which generally have a hypidiomorphic-granular texture; locally in most intrusions, these rocks are porphyritic with both quartz and feldspar phenocrysts. Although both rocks contain as much as 20 percent biotite as the major mafic mineral, most of these rocks are leucocratic; muscovite is common in the granodiorite but is rare in the trondhjemite. At the southeastern and southwestern margins of the Wadsworth stock, contamination of trondhjemitic magma by carbonate metasediments produced contaminated trondh-

ODM7505

Photo 11–Contaminated intrusive breccia of the Glanmire Complex. Rotated, tactite, fragments (dark-grey) are in a matrix of medium-grained quartz monzonite. Lot 28, concession XIII, Tudor Township.

jemite, a massive, medium-grained, quartz-poor rock consisting largely of plagioclase and hornblende, and amphibole trondhjemite which contains as much as 10 percent hornblende.

GLANMIRE COMPLEX

The Glanmire Complex, which covers an area of about 6 square miles in northwestern Tudor Township, was emplaced in three main centres of intrusion: 1) a southern intrusive centre between the Tudor Gabbro and Glanmire Lake; 2) a central intrusive centre between Glanmire Lake and the Beaver Creek Complex; and 3) a small northwestern intrusive centre immediately south of Beaver Creek. In approximate order of emplacement, the major rock types exposed in the complex are: 1) metagabbro and uralitized gabbro; 2) fine-grained albite granite; 3) medium-grained albite granite and rare trondhjemite; and 4) granodiorite and minor trondhjemite. Intrusion of the gabbroic rocks by the albite granite produced: 1) hybrid diorite, which is a medium-grained rock composed mainly of altered, zoned plagioclase (An_{25-32}) and chloritized amphibole; and 2) hybrid albite granite which is a medium- to coarse-grained rock composed mainly of quartz, albite, and amphibole. In the southern intrusive centre, contamination of sodic granitic magma by marble produced contaminated intrusive breccia consisting of abundant, angular, tactite fragments in a potassic leucogranite and leucocratic quartz monzonite matrix (Photo 11). Roof pendants and breccias containing angular mafic metavolcanic fragments are abundant in the northern

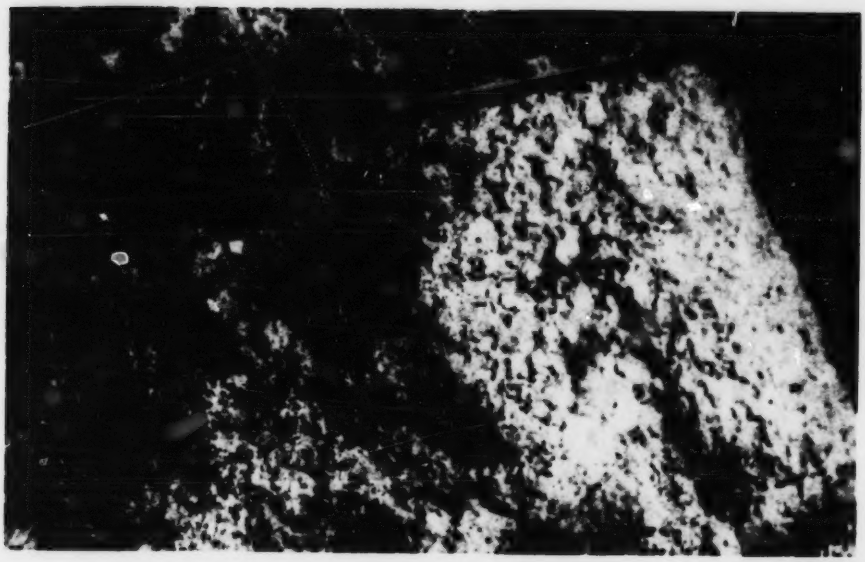

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Photo 12–Irregularly shaped nests of potassic, syenite pegmatite intruded into contaminated intrusive breccia of the Glanmire Complex, lot 28, concession XIII, Tudor Township.

part of the central intrusive centre and the eastern part of the southern intrusive centre. Nests of potassic granite and syenite pegmatites are abundant locally in the contaminated intrusive breccia (Photo 12); elsewhere in the complex, rare potassic granite pegmatite nests are found in albite granite, but distinct dikes are absent. Quartz veins, some of which contain abundant tourmaline, are the youngest phase of the complex.

BEAVER CREEK COMPLEX

The Beaver Creek Complex, which is immediately north of the Glanmire Complex, is exposed over about 1¾ square miles, and a small satellitic body of albite syenite west of the complex is not more than about 650 feet across. In approximate order of emplacement, the major rock types found in the complex are: 1) fine-grained albite syenite and granite; 2) medium-grained albite syenite and amphibole-rich albite syenite; 3) medium-grained albite granite and minor trondhjemite; and 4) a few, fine-grained, albite granite dikes. Breccias composed of: 1) recrystallized, fine-grained albite granite and syenite fragments in a coarse-grained marble matrix; 2) recrystallized, fine-grained, albite granite fragments in a chloritic matrix; and 3) recrystallized, fine-grained, albite granite fragments in an amphibole-rich albite syenite matrix are exposed in two zones in the south-central part of the complex. A narrow zone of breccia containing recrystallized, fine-grained, albite granite fragments in a chlorite- and amphibole-rich matrix is exposed on Highway 62 at the northeastern tip of the complex.

WENDSLEY LAKE ALBITE GRANITE

Hewitt and James (1955, p. 10-11) concluded that the Wendsley Lake Albite Granite probably represents a series of rhyodacitic welded tuffs which are overlain and underlain by marble of the Dungannon formation. Data collected by the author, on the other hand, show that the Wendsley Lake body was intruded into the Dungannon formation and is composed largely of recrystallized albite granite and minor recrystallized sodic granite. According to Hewitt and James, fine-grained white tuff(?) beds are present in the Wendsley Lake body; these are probably the gneissic phases of the granites. Features of the body indicative of an intrusive origin are: 1) hornfelsed metasedimentary inclusions; 2) metagabbro and metadiorite inclusions; 3) granite pegmatite nests; 4) dikes and apophyses of the granites in country rocks adjacent to the body; 5) local discordant contacts; 6) evidence of contact metamorphism of adjacent country rocks; and 7) relic primary textures in the albite granite. Furthermore, the modal composition of the albite granite and a chemical analysis of the granite given by Hewitt and James indicate that the albite granite is mineralogically and chemically similar to the albite granites found in the Beaver Creek and Glanmire Complexes.

MINOR ALBITE GRANITE AND SYENITE STOCKS

Albite granite and syenite of the 14 minor stocks in northern Tudor Township and southern Limerick Township are predominantly fine-grained and porphyritic. Pegmatite is absent, contaminated varieties are present, and the rocks are petrographically similar to the albite granite and syenite of the Glanmire, Beaver Creek, and Wendsley Lake stocks. Rocks of the two stocks in Limerick Township, which were emplaced in the almandine amphibolite facies terrane, were partly recrystallized by the regional metamorphism.

TRONDHJEMITE STOCKS

The two trondhjemite stocks in Tudor Township, which were emplaced in the greenschist facies terrane, consist mainly of massive to poorly foliated trondhjemite. The Grimsthorpe stock contains some granite pegmatite dikes, and near the borders of the stock, the trondhjemite is foliated locally. The main features of the Wadsworth stock are: 1) it appears to be a southwest plunging, crudely-shaped sheet; 2) an early albite granite phase is present at the southwestern end; 3) near the northwestern margin, the trondhjemite is intensely foliated; 4) at the southwestern end and southeastern margin, which on structural evidence appear to dip outward, the trondhjemite was contaminated and desilicated by the carbonate metasediments which were extensively metasomatized; 5) pegmatite dikes are absent; and 6) a few, late, fine-grained, porphyritic albite syenite dikes are present within the southeastern part of the contact metamorphic aureole.

The two trondhjemite stocks in northern Limerick Township consist mainly of foliated trondhjemite, but minor granodiorite and granite pegmatite dikes are present. Metagabbro is present in the eastern part of the most southerly intrusion. Syenite of the Umfraville Gabbro intruded trondhjemite of the most northerly stock; within 600 feet of the syenite, the trondhjemite is partly recrystallized and contains coarse quartz aggregates and minor orthopyroxene.

Mafic Intrusive Rocks

GENERAL

Mafic intrusive rocks consisting of gabbro, diorite, quartz-bearing diorite, tonalite, pyroxenite, and peridotite form five major stocks in the map-area: the Lingham Lake, the Tudor, the Thanet, the Jocko Lake, and the Umfraville stocks. In addition, five minor stocks are present; three are near the Lingham Lake stock, and two are near Limerick Lake. The mafic rocks are largely unaltered in the Umfraville stock, but in the mafic rocks of the other stocks, primary ferromagnesian minerals are largely altered to secondary minerals, and, locally, plagioclase is saussuritized.

Gabbro and diorite, which are composed largely of plagioclase and pyroxene and vary greatly in composition and texture, are present in all the stocks and form most of the Tudor, the Umfraville, and the minor stocks. Gabbro and diorite generally contain more than 35 percent pyroxene, but anorthositic varieties of these rocks containing 15 to 35 percent pyroxene are present in some of the major stocks. Hornblende diorite containing primary hornblende, anorthosite containing less than 10 percent pyroxene, and olivine gabbro containing as much as 50 percent olivine are rare. Gabbros and diorites, in which pyroxene is completely uralitized and plagioclase is completely saussuritized, are termed metagabbro and metadiorite. In most of the stocks this alteration is found only locally and is due to autometamorphism. Nevertheless, metagabbro and metadiorite exposed in the peninsula at the northwest end of Limerick Lake were formed by regional metamorphism and consist of amphibolite with a poorly oriented fabric and hornblende-plagioclase gneiss. Tonalite, which is characterized by abundant biotite, by primary hornblende, and by more than 10 percent quartz, and quartz-bearing diorite, which is characterized by minor biotite, by abundant uralitized pyroxene, and by less than 10 percent quartz, are abundant in the Lingham Lake, Thanet, and Jocko Lake stocks but are either absent or rare in the other stocks. Minor pyroxenite, which contains more than 90 percent pyroxene, is present in all the major stocks, and peridotite, which is composed largely of olivine and pyroxene, is present sparingly in the Lingham Lake, Tudor, and Umfraville stocks. These ultramafic rocks are commonly altered to metapyroxenite and to metaperidotite which are composed of various mixtures of serpentine, chlorite, talc, amphibole, carbonate, and iron-titanium oxide minerals. Texturally, the plagioclase-bearing mafic rocks are generally hypidiomorphic-granular and foliated, but the grain size, crystal habit, and fabric orientation vary greatly. For the most part, the foliation, which is due to alignment of plagioclase tablets and pyroxene prisms, is a primary flow layering. Gabbro and diorite rich in ferromagnesian minerals are commonly massive and have an ophitic texture. The ultramafic rocks are generally medium-grained and massive, but coarse-grained varieties are found.

Age relationships of the mafic intrusive rocks are complex. One minor mafic intrusion in Limerick Township was recrystallized by the regional metamorphism, and mafic intrusive rocks are early phases in some albite granite and syenite stocks which also were emplaced before the culmination of the regional metamorphism. Nevertheless, the major mafic stocks and most of the minor mafic

Table 7 | MODAL AND CHEMICAL COMPOSITIONS OF GABBROS AND DIORITES

SAMPLE NUMBER	1	2	3	4	5	6	7	8	9
				MODES (VOLUME PERCENT)					
Plagioclase	51.4	17.8	68.9	57.1	69.8	44.0	32.9	68.5	46.3
Percent An	55	65	50	55	55	55	50	40	40
Quartz	....	....	Trace	....	....	....	....	....	0.7
Biotite	5.7	1.0	5.3	Trace	....	0.6	0.6	Trace	1.4
Uralitized Pyroxene	....	....	....	38.8	28.5	50.1	60.0	28.3	46.4
Clinopyroxene	21.4	31.6	18.2	....	....	....	....	....	....
Orthopyroxene	13.5	15.8	1.0	....	....	....	....	....	....
Olivine	Trace	26.5	....	....	....	....	....	....	....
Carbonate	....	1.0	....	....	....	....	....	....	....
Apatite	1.1	0.2	1.4	0.1	0.1	0.7	1.0	0.6	1.3
Opaque Minerals	6.9	6.1	4.5	4.0	1.6	4.6	5.5	2.6	3.1
Others	....	....	0.7	....	....	....	....	....	0.8
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
				CHEMICAL ANALYSES (WEIGHT PERCENT)*					
SiO_2	45.48	....	47.77	46.89	....	48.61	48.23	....	49.94
Al_2O_3	14.62	....	19.63	18.90	....	17.20	15.32	....	18.67
Fe_2O_3	5.76	....	3.57	2.93	....	2.02	2.56	....	1.73
FeO	7.30	....	4.17	6.63	....	6.58	6.82	....	6.89
MgO	8.60	....	4.85	6.98	....	8.41	9.70	....	6.27
CaO	11.43	....	12.60	11.17	....	10.45	11.13	....	9.05
Na_2O	2.14	....	2.92	2.34	....	2.32	2.01	....	3.32
K_2O	0.51	....	1.03	0.27	....	0.29	0.31	....	0.34
H_2O+	0.54	....	0.32	0.89	....	1.01	0.84	....	0.78
H_2O-	0.20	....	0.10	0.16	....	0.05	0.07	....	0.08
CO_2**	0.22	....	1.18	1.01	....	1.11	1.05	....	0.74
TiO_2	1.90	....	1.13	1.61	....	0.98	1.15	....	1.14
P_2O_5	0.31	....	0.38	0.04	....	0.33	0.22	....	0.11
MnO	0.18	....	0.11	0.12	....	0.13	0.15	....	0.10
Cr_2O_3	0.07	....	0.01	0.02	....	0.02	0.05	....	0.03
V_2O_3	0.05	....	0.02	0.04	....	0.03	0.03	....	0.01
Totals	99.31		99.79	100.00		99.54	99.64		99.20

*Chemical analyses by Laboratory Branch, Ontario Department of Mines.

**Calculated from loss on ignition.

SAMPLES:

1–Unaltered gabbro. Average of five modes from Umfraville Gabbro; chemical analysis made from a composite sample composed of equal amounts of the same five specimens used to determine the average mode.

2–Olivine gabbro. Average of three modes from Umfraville Gabbro.

3–Anorthositic gabbro-diorite. Average of five modes from Umfraville Gabbro; chemical analysis made from a composite sample composed of equal amounts of the same five specimens used to determine the average mode.

4–Uralitized gabbro. Average of 24 modes from Tudor Gabbro; chemical analysis made from a composite sample composed of equal amounts of the same 24 specimens used to determine the average mode.

5–Anorthositic gabbro. Average of 14 modes from the Tudor Gabbro.

6–Uralitized gabbro. Average of six modes from Thanet Complex; chemical analysis made from composite sample composed of equal amounts of the same six specimens used to determine the average mode.

7–Uralitized gabbro. Average of seven modes from Jocko Lake Complex; chemical analysis made from composite sample composed of equal amounts of the same seven specimens used to determine the average mode.

8–Anorthositic diorite. Average of eight modes from Tudor Gabbro.

9–Uralitized diorite. Average of six modes from the Thanet Complex; chemical analysis made from composite sample composed of equal amounts of the same six specimens used to determine the average mode.

stocks have well developed contact metamorphic aureoles and were emplaced after the culmination of the regional metamorphism and after the albite granite and syenite stocks. Because all the major mafic stocks except the Umfraville Gabbro show trondhjemitic differentiation trends and have average modal compositions that range from diorite to rocks intermediate between diorite and tonalite, they are probably either slightly older than, or coeval with, the trondhjemite stocks. The Umfraville Gabbro, in which successively younger fractions of the crystallizing magma were enriched in potassium, intruded one of the trondhjemite stocks. Geochronologic studies of the felsic intrusive rocks in the map-area and adjacent townships (Silver and Lumbers 1966) show that the sodic granitic and syenitic rocks form a distinct age group, about 1,250 ± 25 million years, in which rocks from the albite granite and syenite stocks are slightly older than some rocks from trondhjemite stocks. Syenite of the Umfraville stock is distinctly younger than 1,250 ± 25 million years.

LINGHAM LAKE COMPLEX

The Lingham Lake Complex, which is a discordant, composite intrusion occupying an area of about 33 square miles in western Grimsthorpe Township and eastern Tudor Township, is circular in plan and was mapped in Grimsthorpe Township by Meen (1942). The western third of the complex in Tudor Township consists mainly of three, separate, heterogeneous, mafic intrusive units which were probably emplaced in the following order: 1) metapyroxenite and metaperidotite; 2) uralitized gabbro and diorite; and 3) quartz-bearing diorite and tonalite. Although intrusion breccias and sharp contacts between the three intrusive units are found locally, gradational contacts and locally contradictory sequential age relationships are most common and suggest that successive units were intruded rapidly. Heterogeneity of the three units results mainly from patchy gradational variations and rarely from crude layering and erratic veining. Heterogeneity is less pronounced in the ultramafic rocks than in the other intrusive units in which the rock types are so complexly intermingled that extremely detailed study would be required to separate them. Some differentiation in place may have occurred locally within the ultramafic and gabbroic units; the ultramafic rocks, which are near the southern margin of the complex, form an irregularly shaped unit which shows a crude, compositional zoning with metaperidotite containing copper and nickel mineralization (see "Triana Exploration Ltd." section) concentrated in the central part and metapyroxenite concentrated near the margins.

In general, the mafic phases show a crude zonal distribution with the late quartz-bearing mafic rocks concentrated within the interior of the complex and the early, quartz deficient, mafic rocks concentrated near the borders. Although this distribution might suggest that the ultramafic and gabbroic units may have evolved through contamination of a more felsic magma by the mafic metavolcanic country rocks, the scarcity of metavolcanic inclusions within these mafic rocks and the contact relationships of the ultramafic and gabbroic units, which indicate that they are discrete intrusions, show that such contamination did not occur. Moreover, mafic metavolcanic inclusions are most abundant in the quartz-bearing mafic units.

Fine- to medium-grained gabbro and diorite dikes intruded the major mafic phases of the complex, but are older than trondhjemite and granodiorite found locally in the complex near the eastern boundary of Tudor Township. Some deformed and disrupted hornblende gabbro dikes, which contain coarse-grained, poikilitic hornblende crystals with labradorite and pyroxene inclusions, may have been emplaced before the earlier mafic units were completely crystallized. A few small granite pegmatite dikes intruded the trondhjemite and granodiorite and, rarely, the older mafic rocks.

TUDOR GABBRO

The Tudor Gabbro, which extends from west-central Lake Township into east-central Tudor Township, is crudely elliptical in plan with a northeastern elongation and has an area of about 12 square miles. After early reconnaissance work on the intrusion by Adams and Barlow (1910, p. 151-152), the western third of the body in Lake Township was mapped in detail by Laakso (1963; 1968).

In Tudor Township, the intrusion, which was emplaced in folded carbonate metasediments and mafic metavolcanics, is composed mainly of uralitized gabbro and uralitized diorite in which the plagioclase commonly has a purplish tint due to abundant inclusions of fine-grained hematite and hemoilmenite, and in which the average uralitized pyroxene content is close to 35 percent. Anorthositic gabbro and diorite are common within the intrusion, and just west of the Hastings Road an elongate mass of altered anorthosite composed mainly of saussuritized plagioclase is present. Coarse-grained gabbro and diorite with nests of pegmatitic gabbro and diorite are common, particularly near contacts with carbonate metasediments; fine-grained border phases of the diorite and gabbro are rare at carbonate metasediment contacts but are common locally at mafic metavolcanic contacts. The diorite, which is concentrated near the borders of the intrusion, almost completely encloses the gabbro, and both rocks are gradational at their contacts; anorthositic phases of these rocks grade irregularly into the more mafic gabbro and diorite. In places, the gabbro and diorite are intermingled and exhibit primary, discontinuous, compositional layering marked by rhythmic alternations of felsic-rich and mafic-rich layers less than 1 foot thick (Photo 13).

Averages of 24 uralitized gabbro modes, 14 anorthositic gabbro modes, 8 anorthositic diorite modes, and a chemical analysis of the uralitized gabbro are listed in Table 7. In the analysis of the gabbro, the high soda to potassia ratio reflects the scarcity of potassic feldspar in rocks of the intrusion and the relatively sodic plagioclase in the gabbro and diorite; the relatively high alumina content reflects the generally high plagioclase content.

Although the gabbro and diorite locally contain relic pyroxene, complete uralitization and saussuritization of these rocks are common, particularly near their junction with the carbonate metasediments. Most commonly, uralitization and saussuritization are concentrated along joints, but where evidence of movement, such as slickensides, is present along joints or in the vicinity of faults and shear zones, uralitization and saussuritization are distributed irregularly over relatively large areas of the intrusive rocks.

ODM7507

Photo 13–Discontinuous compositional layering in uralitized gabbro of the Tudor Gabbro, lot 48, west of Hastings Road, Tudor Township.

At the southern margin of the intrusion in lot 24, concession VIII, Tudor Township, partly altered pyroxenite and peridotite, which form a zone about 2,400 feet long and as much as 700 feet wide, grade into uralitized gabbro and metagabbro. A few metapyroxenite dikes are found locally in the gabbroic and dioritic rocks of the intrusion, and at the Orton mine south of Mann Lake, massive stringers of ilmenomagnetite are associated with metapyroxenite dikes (see "Orton Mine" section). The youngest phases of the intrusion in Tudor Township are fine-grained diorite dikes, which are found throughout the body, and trondhjemite, minor granodiorite, and rare granite pegmatite near the northeastern margin of the intrusion.

Two dikes of the Glanmire Complex, one consisting of albite syenite in lot 28, concession IX, and the other consisting of albite granite in lot 26, concession X, Tudor Township, are within the contact metamorphic aureole of the Tudor Gabbro and were intruded and metamorphosed by diorite of this intrusion.

THANET COMPLEX

Crudely elliptical in plan, the Thanet Complex, which is exposed in southeastern Wollaston Township and southwestern Limerick Township, is a composite intrusion with an area of about 9 square miles. The eastern part of the Complex in Limerick Township contains concentrations of copper and nickel in dikes and irregularly shaped bodies of metapyroxenite (see "Macassa Gold Mines Ltd." section). Adams and Barlow (1910, p. 150-151) first mapped the complex, and the Wollaston Township portion was re-mapped in greater detail by Hewitt (1962, p. 40-41).

On the basis of field relationships, most of the complex in Limerick Township can be divided into three, separate, lithologically distinct, intrusive units which were emplaced in the following order: 1) uralitized gabbro and minor uralitized diorite; 2) uralitized diorite and minor uralitized gabbro; and 3) tonalite and quartz-bearing diorite. Each unit is characterized by heterogeneous compositions and textures, and all three units are in contact with one another. In places, contacts between the three units are either marked by narrow zones of hybrid intrusive rocks, or disrupted with zones of intrusion breccia; commonly, however, gradational contacts and local, contradictory, sequential age relationships are present. These features suggest relatively rapid successive intrusion of the three units beginning with the uralitized gabbro and ending with the tonalite and quartz-bearing diorite. Sharp contacts and intrusion breccias are most common at contacts between the oldest and youngest of the three phases. Following their complete crystallization, the three major intrusive units were intruded by dikes and irregularly shaped masses of unaltered gabbro and unaltered diorite. Metapyroxenite dikes, which are particularly abundant near the eastern and southeastern borders of the complex, were emplaced after each of the preceding intrusive episodes, but most of the dikes are closely associated in space and in time with uralitized gabbro and uralitized diorite. Fine-grained diorite dikes, which are most abundant in the uralitized gabbro, are the youngest rocks of the complex in Limerick Township.

Modal and chemical analyses of uralitized gabbro and uralitized diorite, which are the most abundant rocks of the complex in Limerick Township, are listed in Table 7. As a group, the three major phases of the complex show a trondhjemite differentiation trend, and their petrographic similarities and rapid successive intrusion suggest a common source. Although minor differentiation in place and contamination by country rocks may have occurred, structural relationships and the distinct lithologies of the three major phases demonstrate that they differentiated at a lower level. Preponderance within the complex of rocks of dioritic to tonalitic composition suggests that the average modal composition of the complex is intermediate between diorite and tonalite.

JOCKO LAKE COMPLEX

The Jocko Lake Complex, which is near the centre of Limerick Township, is a composite intrusion which is circular in plan and has an area of about 3 square miles. The intrusion, which was emplaced mainly within a folded metagreywacke sequence, has a core composed of uralitized gabbro and minor uralitized diorite which is surrounded by a margin composed of quartz-bearing diorite and minor tonalite and uralitized diorite. These mafic rocks were intruded by three lithologically distinct phases which form dikes and irregularly shaped masses and which were emplaced in the following order: 1) metapyroxenite which is found mainly in the gabbroic core; 2) coarse-grained to pegmatitic hornblende gabbro and hornblende diorite which are confined to the central part of the complex; and 3) fine-grained diorite dikes. Trondhjemite, granodiorite, and granite pegmatite are the youngest rocks of the complex; granodiorite and most of the trondhjemite form a large mass in the northeastern part of the intrusion, but a few small masses and dikes of trondhjemite are present elsewhere in the complex. Granite pegmatite dikes are found sparingly in the granodiorite-trondhjemite mass, and near the zone of coarse-grained to pegmatitic gabbro and diorite in the central part of the complex.

Modal and chemical analyses of uralitized gabbro from the core of the complex are listed in Table 7. The uralitized gabbro, which is richer in ferromagnesian minerals than gabbros from other mafic stocks in the area, commonly grades into the marginal diorite-tonalite phase through a narrow zone of diorite which contains less uralitized pyroxene than the gabbro and as much as 5 percent biotite. Locally, gabbro near the core border was intruded by dikes and irregularly shaped masses of quartz-bearing diorite and anorthositic diorite, and within the gabbro core, two patches of dioritic rocks intruded the gabbro. These features suggest that the gabbro is older than the dioritic rocks, and the gradational contacts suggest that the dioritic rocks were intruded shortly after the gabbro. Nevertheless, the presence locally of abundant metagreywacke inclusions within the marginal diorite-tonalite mass might suggest that this mass may be contaminated gabbro. The following features indicate that the rocks of this mass form a separate intrusion: 1) intrusion breccias are found locally at contacts between the marginal phase rocks and the gabbro of the core; 2) diorite and quartz-bearing diorite, the most mafic rocks of the marginal phase, commonly occur at contacts with metagreywacke; and 3) in the southern part of the marginal phase, where metagreywacke inclusions are most abundant, tonalite is rare.

UMFRAVILLE GABBRO

The Umfraville Gabbro, which is centred about three-quarters of a mile west of the common corner boundary of Wollaston, Faraday, Dungannon, and Limerick Townships, is a gently curved, elongate intrusion with a maximum east-west length of 6 miles. From its western end where it is as much as 2½ miles wide, the intrusion tapers eastward and is about 1½ miles wide at its eastern end. Only the eastern third of the intrusion is within the map-area. Adams and Barlow (1910, p. 149-150) first mapped the intrusion, and Hewitt and James (1955) and Hewitt (1957; 1962) remapped those portions of the intrusion in Dungannon, Faraday, and Wollaston Townships.

In Limerick Township, the Umfraville Gabbro consists largely of olivine gabbro, pyroxenite, unaltered gabbro, and anorthositic gabbro and diorite. Potassic syenite and minor pyroxene monzonite intruded these mafic rocks and were, in turn, intruded by granite pegmatite dikes. In contrast to the commonly uralitized mafic intrusive rocks of the other intrusions in the map-area, the mafic rocks of the Umfraville Gabbro are largely unaltered; orthopyroxene which has a submetallic, bronzy lustre, clinopyroxene which is generally dark-green to black, and plagioclase which has a purplish tint due to abundant inclusions of fine-grained iron-titanium oxide minerals, are easily identified in hand specimen. Nevertheless, near granite pegmatite dikes, the mafic rocks are completely uralitized and saussuritized.

Olivine gabbro, pyroxenite, and gabbro grade irregularly into one another, and, in places, all three rock types are complexly intermingled. Olivine gabbro, which forms two zones, one extending across Bear Shanty Lake and the other south of Bear Shanty Lake, commonly exhibits poorly developed mineral layering with olivine gabbro layers grading into pyroxenite and, rarely, peridotite layers. In islands in Bear Shanty Lake, disturbed rhythmic layering was found in olivine gabbro and pyroxenite. Gabbro commonly contains aligned, lens-like, pyroxene and plagioclase aggregates less than 1 foot long. Anorthositic gabbro and diorite in the southeastern part of the intrusion generally grade into gabbro, but, locally, dikes of these rocks are found in the gabbro; plagioclase in the anorthositic rocks commonly contains exsolved films of potassic feldspar. Modal and chemical analyses of olivine gabbro, unaltered gabbro, and anorthositic gabbro and diorite are listed in Table 7.

Most of the potassic syenite is in sharp contact with unaltered gabbro, and a few syenite dikelets are found locally in all the mafic intrusive rocks. In a few places east of Bear Shanty Lake, gabbro dikelets were found in syenite at the contact of these rocks. North of John Lake, both the syenite and the gabbro were mylonitized at their contact. Pyroxene monzonite is found mainly at contacts of the syenite and the anorthositic gabbro and diorite, and appears to be a hybrid phase. These relationships suggest that the syenite may have been intruded before the mafic and anorthositic rocks were completely crystallized.

MINOR MAFIC INTRUSIONS

In Tudor Township, three minor mafic intrusions are found near the Lingham Lake Complex. Two of the intrusions are composed of massive, uralitized gabbro, one in the north half of lot 6, concession II, and the other in lots 5 and 6, concession XIII, which is a sill separating felsic metavolcanics on the west from mafic metavolcanics on the east. Both bodies, which intruded mafic metavolcanics in the outer part of the contact metamorphic aureole of the Lingham Lake Complex, may be genetically related to the complex. In lot 6, concessions XIII and XIV, massive, medium-grained metagabbro, which has a hypidiomorphic-granular texture, forms a stubby, north-trending dike. Locally, near the borders of the dike, the metagabbro is fine-grained.

An elliptical diorite intrusion in lots 8 to 10, concession V, Limerick Township, is about 3,300 feet long and as much as 2,300 feet wide. Rocks in the eastern end of the intrusion vary greatly in composition and in texture, and consist of massive metagabbro and hornblende gabbro with numerous irregularly shaped patches and dikes of less mafic-rich, massive metadiorite and hornblende diorite. This eastern heterogeneous unit grades westward into massive hornblende diorite, which contains coarse-grained hornblende prisms as much as 5 inches long, and forms most of the central and western parts of the intrusion. In a few places, the hornblende diorite was intruded by dikes and irregularly shaped patches of massive, medium-grained, quartz-bearing rocks ranging in composition from quartz-bearing hornblende diorite to trondhjemite. Late, fine-grained diorite dikes are common in the western part of the intrusion.

In lots 15 and 16, concessions V and VI, Limerick Township, two small metagabbro and metadiorite masses are exposed in the peninsula at the northwestern end of Limerick Lake. Rocks of both masses underwent regional metamorphism and consist of fine- to medium-grained hornblende prisms in a much finer-grained, equigranular matrix composed largely of zoned oligoclase-andesine granules, pistacite, calcite, and minor quartz. The irregular shape of the masses, together with the conformable structural pattern in the adjacent country rocks, suggest that both masses are part of a folded metagabbro-metadiorite sheet.

Mafic Sills and Dikes

In northern Tudor Township and southeastern Limerick Township, mafic sills and dikes are abundant in a northeasterly-trending zone, ½ to 2 miles wide, which extends from Brett Lake at the northwestern boundary of Tudor Township, to the southeastern boundary of Limerick Township. In general, the sills and dikes, which intruded all the intrusive stocks present in the zone, trend northeast parallel to the trend of the St. Ola Fault and to the major structural trends in the metasediments and metavolcanics. Major features of the sills and dikes are: 1) most of the intrusions are less than 100 feet wide and can be traced for only short distances, but one sill in northwestern Tudor Township is as much as 400 feet wide and can be traced for about 2 miles; 2) along strike, the sills and dikes pinch and swell, and branching is common; 3) along strike, the sills commonly transgress bedding in host metasediments and become markedly discordant dikes; 4) commonly, quartz and quartz-carbonate veins found within the intrusions are oriented nearly perpendicular to the walls of the sills and dikes, and rarely do such veins extend into the adjacent country rocks; 5) fine-grained border zones are present in some sills and dikes; 6) locally, foliation is visible near the margins of the intrusions; 7) country rocks underwent contact metamorphism for as much as 2 feet from the margins of the intrusions; 8) mafic rocks, which form the sills and dikes, are invariably altered; and 9) in northern Tudor Township, mafic sills and dikes in the mafic metavolcanics and in the Glanmire Complex show the same trends and features as the mafic sills and dikes in the main zone, and all these mafic intrusions are probably related in age and in origin.

Massive, medium-grained, metagabbro and metadiorite constitute most of the sills and dikes. Although the primary mineral assemblages are largely altered, deformation is rare, and primary textures are generally well preserved; most of these rocks are hypidiomorphic granular, but a few are ophitic. Plagioclase generally forms 40 to 50 percent of the rocks, but, locally, the rocks are extremely rich in uralitized pyroxene and are close to metapyroxenite in composition. Preservation of primary microtextures, the scarcity of deformation, and the presence of contact metamorphic aureoles in adjacent country rocks suggest that the alteration of these mafic intrusions may be due to autometamorphism rather than to regional metamorphism.

Potassic Granitic and Syenitic Rocks

Potassic granitic and syenitic rocks, which are characterized by abundant potassic feldspar and by low soda to potassia ratios, consist of potassic syenite, monzonite, quartz monzonite, potassic granite, granite pegmatite, and syenite pegmatite. The pegmatites are found as late phases of some mafic and sodic granitic and syenitic stocks, whereas the other rocks either form separate stocks which are probably the youngest intrusions in the map-area, or are late phases of the Umfraville Gabbro. All the rocks of the group are massive and only slightly altered, and with the exception of some of the monzonite, they are leucocratic.

Potassic syenite is a late phase of the Umfraville Gabbro and forms most of the small stock in southeastern Limerick Township and most of the Mount Moriah Syenite exposed in southeastern Tudor Township. The rock, which is composed largely of potassic feldspar and plagioclase, is equigranular to porphyritic, medium-grained to rarely coarse-grained, and pink- to mauve-weathering. Biotite is the chief ferromagnesian mineral, but, locally in the Umfraville Gabbro and in the Mount Moriah Syenite, hornblende is present. Potassic feldspar, which forms as much as 85 percent of the rock, is perthitic, and plagioclase is generally zoned albite-oligoclase; plagioclase of the syenite in southeastern Limerick Township is slightly zoned albite. Common accessory minerals in the syenite are quartz, sphene, zircon, and apatite; as much as 10 percent magnetite is present in the syenite of the Umfraville and Mount Moriah stocks. The proportion of plagioclase to potassic feldspar varies greatly in the syenite, and in the Umfraville and Mount Moriah stocks, the syenite grades locally into monzonite. In the Umfraville Gabbro, the monzonite commonly contains 20 to 30 percent ferromagnesian minerals, mainly uralitized clinopyroxene.

Medium-grained, pink quartz monzonite, which contains 10 to 30 percent quartz and 60 to 80 percent feldspar consisting of about equal amounts of zoned albite-oligoclase and potassic feldspar, forms local phases in the Mount Moriah Syenite and a few dikes in the contact metamorphic aureoles of 1) the Umfraville Gabbro near the northwest boundary of Limerick Township, and 2) the Gawley Creek stock in the southwest corner of Tudor Township. Pink, medium-grained, potassic granite, which contains 20 to 25 percent quartz and 65 to 70 percent feldspar consisting of about equal amounts of albite and potassic feldspar, is found only in the syenite stock in southeastern Limerick Township. Biotite is the chief ferromagnesian mineral in both the quartz monzonite and the potassic granite; some quartz monzonite in southwestern Tudor Township contains accessory purple fluorite.

Most of the granite pegmatite forms narrow dikes and nests, but in the Umfraville Gabbro, dikes as much as 350 feet wide are present. The granite pegmatite is composed of quartz and potassic feldspar and minor amounts of sodic plagioclase, muscovite, and biotite. Coarse-grained tourmaline crystals are common in granite pegmatite in the Umfraville Gabbro. Syenite pegmatite which consists mainly of intergrown crystals of potassic feldspar (see Photo 12) is found as nests in the contaminated intrusion breccia of the Glanmire Complex and in carbonate metasediments of the contact metamorphic aureole of the Tudor Gabbro.

PALEOZOIC SEDIMENTARY ROCKS

The Paleozoic sedimentary rocks of the map-area are represented by a small outlier of the Shadow Lake Formation of Middle Ordovician age in the southeast corner of Tudor Township. The outlier is one of several near the southern border of the Cashel peneplane (see "Bedrock Geology", "Preliminary Statement" section), and it is probable that early Paleozoic sedimentary rocks once mantled the entire peneplane.

Shadow Lake Formation

The Shadow Lake Formation was defined by Okulitch (1939) and redefined by Liberty (1955). According to Liberty (1963) the formation consists of "red and green shales with some sandstone and arkose", and ranges in thickness from 0 to 50 feet. In Tudor Township, the formation is poorly exposed and consists mainly of quartz-rich red siltstone and sandstone which commonly contain a few scattered quartz pebbles. One exposure of the formation in lot 1, concession I, consists of interbedded arkose and pebble conglomerate which contains quartz, feldspar, and red sandstone and siltstone pebbles in an arkosic matrix. A few boulders of grey, lithographic limestone, which were probably derived from the Gull River Formation (Liberty 1963), were found in the vicinity of exposures of the Shadow Lake Formation, but no bedrock exposures of the limestone are present. Liberty (1963) concludes that the Shadow Lake Formation is Middle Ordovician in age and that it correlates paleontologically with the Pamelia Formation.

LATE CALCITE AND QUARTZ FISSURE VEINS

Calcite and quartz veins, which are fillings of fault fissures, are locally abundant in marble-rich areas in southern and northwestern Tudor Township and in southwestern Limerick Township. The veins generally strike northwestward nearly perpendicular to the general northeasterly strike of the host country rocks. A few of the veins cut across the mafic sills and dikes, and south of the map-area in Madoc Township, veins, which are similar in both mineral composition and attitude to those within the map-area, are fissure fillings in Ordovician sedimentary rocks stratigraphically above the Shadow Lake Formation (Uglow 1916; Guillet 1964). The veins in the map-area appear to be part of a regional, northwesterly-trending group of fissure veins which: 1) extend over a large part of southeastern Ontario and adjacent parts of New York State (Uglow 1916); 2) are younger than most of the Paleozoic sedimentary rocks in this region; and 3) parallel the trend of, and are associated locally with, block-faulting in the Ottawa Valley and Madawaska highlands which is assigned to the Tertiary by Kay (1942b).

In the map-area, the veins consist either of calcite with minor amounts of quartz, barite, galena, sphalerite, pyrite, and a trace of light-green fluorite, or of quartz with minor amounts of calcite, chalcopyrite, pyrite, sphalerite, tourmaline, and rarely, galena. Both vein types occur together and they share the following features: 1) slickensided walls; 2) angular inclusions of adjacent country rocks are common but are most abundant in the calcite veins; 3) many of the veins can be traced for long distances along the strike (as much as 3,600 feet), but some veins appear to be *en échelon* lens-like bodies; 4) the veins pinch and swell both along the strike and down the dip; 5) many of the veins are vertical; 6) most of the veins are drusy, particularly in the central part and comb structure is common in the calcite veins; and 7) the vein minerals are generally coarse-grained. Because of their mineralization, many of the veins have undergone extensive exploration and development, and some lead has been produced from the calcite veins. Details of the exploration, development, and mineralization of the veins are given in the "Economic Geology" section under "Lead and Zinc".

COMPARISON OF BEDROCK GEOLOGY TO AEROMAGNETIC DATA

In Figure 3 (Chart A, back pocket), aeromagnetic data which were obtained from maps published by the Geological Survey of Canada (G.S.C. 1950a and b; 1952) are superimposed on the general lithology of the map-area.

Some empirical relationships shown by the comparison of the aeromagnetic data to the metasedimentary and metavolcanic lithology are:

1. The generalized isomagnetic contours follow the regional structural trends of the metasediments and the metavolcanics.
2. The magnetic intensities of each of the three major metasedimentary groups increase with increasing grade of regional metamorphism. In the clastic siliceous metasediments and calcareous metasandstone and metasiltstone, this increase in magnetic intensity coincides wth progressively greater amounts of accessory pyrrhotite and magnetite in these rocks with increasing grade of metamorphism. In the carbonate metasediments, which have lower magnetic intensities than the other metasedimentary groups, magnetic sulphide and oxide minerals are generally absent in these rocks in the greenschist facies terrane, but accessory pyrrhotite and magnetite are commonly present in these rocks in the almandine amphibolite facies terrane.
3. Greenschist facies metavolcanics have a higher magnetite content and slightly higher magnetic intensities than the almandine amphibolite facies metavolcanics which contain pyrrhotite as the chief sulphide mineral and ilmenite as the chief iron-titanium oxide mineral.

Twenty-one magnetically anomalous areas are present in the metasediments and metavolcanics. The anomalies, which are numbered for reference in Figure 3 (Chart A, back pocket), correlate with: 1) concentrations of magnetite in siliceous iron formation (Nos. 3, 12, 13, 15, 18, and 21); 2) local concentrations of accessory magnetite in the greenschist facies metavolcanics (Nos. 1, 4, 5, 6, 7, and 8); 3) concentrations of magnetite developed in carbonate metasediments by contact metasomatism (No. 11); and 4) concentrations of pyrrhotite in rusty-weathering schists (Nos. 2, 9, 10, 14, 16, 17, 19, and 20). The mild positive anomaly in northern Tudor Township along the metavolcanic-metasedimentary contact, between Beaver Creek and Wadsworth Lake, correlates with the abundance of accessory magnetite in meta-andesite of the Oak Lake formation and with locally abundant rusty-weathering schist zones. Abundance of rusty-weathering schists at the upper and lower boundaries of the Turriff metavolcanics in west-central Limerick Township is reflected by a mild positive anomaly.

The granitic stocks, which contain only minor amounts of magnetic oxide and sulphide minerals, have low magnetic intensities. In the southeast corner of Tudor Township, the abundant accessory magnetite in the Mount Moriah Syenite is reflected by a high positive anomaly. Although accessory iron-titanium oxide minerals are abundant in the mafic stocks, all but the Umfraville Gabbro, which has a high positive anomaly, have neutral to mild positive anomalies, and a mild negative anomaly occurs in the northeastern part of the Tudor Gabbro. In the Thanet and Jocko Lake Complexes, ilmenite and hemoilmenite comprise more than two-thirds, and magnetite less than a third of the opaque oxides, and mild positive anomalies within these complexes can be correlated with local concentrations of pyrrhotite and magnetite in gabbroic and ultramafic phases. Although the iron-titanium oxide minerals have not been studied in the Lingham Lake Complex, its magnetic properties are similar to those of the Thanet and Jocko Lake Complexes, a fact which suggests that here also, magnetite forms a low proportion of the oxide minerals. In the Tudor Gabbro, which has a mild positive anomaly, the iron-titanium oxides are mainly ilmenomagnetite, ilmenite, and hemoilmenite, but magnetite is more abundant than in the Jocko Lake and Thanet Complexes. In rocks underlying the mild negative anomaly in the northeastern part of the Tudor Gabbro, ilmenomagnetite and ilmenite are the predominant iron-titanium oxides. In the Umfraville Gabbro, iron-titanium oxides are mainly magnetite and ilmenite; intermediate solid solution members of the hematite-ilmenite-rutile system are rare.

The neutral to mild positive anomalies shown by the Thanet, Jocko Lake, Tudor, and Lingham Lake bodies appear to be controlled by the magnetic properties of their iron-titanium oxide minerals. Intermediate solid solution members of the hematite-ilmenite-rutile system, which form the largest proportion of the magnetic oxides in these bodies, commonly have reverse remanent magnetism (Balsley and Buddington 1958). If this is so, then these oxide minerals could largely neutralize the positive induced magnetism of the associated magnetite to give the neutral to mild positive magnetic anomalies. In order to check this hypothesis, the orientation of the remanent magnetization in the intrusive rocks of the Umfraville, Jocko Lake, Thanet, and Tudor bodies is being determined.

Hewitt (1962, p. 41) postulates that the neutral to mild positive anomaly of the Thanet Complex is due to recrystallization of the intrusive rocks with magnetite taken up by hornblende. In the map-area, only the regionally metamorphosed mafic intrusions, such as the intrusion at the northwest end of Limerick Lake, are sufficiently recrystallized for magnetite to be taken up by hornblende. The petrology of the Thanet Complex shows that it was not regionally metamorphosed; scarcity of magnetite in the intrusive rocks, therefore, is a primary feature of these rocks. Unaltered gabbro and diorite present in the complex contain the same proportion of magnetite to other iron-titanium oxide minerals as do uralitized gabbro and diorite. Furthermore, most of the hornblende in the intrusive rocks is primary; tremolite and actinolite, not hornblende, are the common replacement minerals in the uralitized pyroxene.

The petrology of the Jocko Lake, Tudor, and Umfraville bodies also indicates that these intrusions were not regionally metamorphosed and that the proportion of magnetite to other iron-titanium oxide minerals has not been appreciably changed by recrystallization. Nevertheless, within these bodies, zones of hydrothermal oxidation do exist in which the iron-titanium oxide minerals are completely oxidized. Such zones, which are relatively small, are developed only locally, and they correlate poorly with the aeromagnetic data.

STRUCTURAL GEOLOGY

Structural data used for the interpretation of the general structure and stratigraphy in the map-area shown in Figure 4 (Chart A, back pocket) are given in Maps 2167 and 2168 (back pocket). The major structural features of the region surrounding the map-area are discussed elsewhere (Lumbers 1967a, 1967b). Parts of two regional domes, the Elzevir-Ashby dome and the Ormsby dome, are present in the map-area. The Elzevir-Ashby dome, which extends north from southern Elzevir Township to northern Ashby Township and east from Tudor Township to western Barrie Township, is underlain largely by the Tudor metavolcanics and contains the Lingham Lake, Mount Moriah, and Grimsthorpe stocks; the Tudor Gabbro, Glanmire, Beaver Creek, and Wadsworth intrusions are near the margin of the dome. The Ormsby dome in central and western Limerick Township, and western Wollaston Township contains the Thanet, Jocko Lake, and the Umfraville stocks, and the Coe Hill, Urbach Lake, and Murphy Corners Anticlines. Metasediments in northern Tudor Township and eastern Limerick Township occupy part of a synclinorium in which axial surfaces of major folds dip west to northwest. Two faults of regional extent, the St. Ola and Limerick Lake Faults, extend across the central part of the area and offset two of the metamorphic isograds.

Folding

In general, the principal fold pattern developed before the culmination of the regional metamorphism, as is indicated by the common occurrence of undeformed, randomly oriented porphyroblasts of various metamorphic minerals in the metasediments and metavolcanics; some minor folds in which biotite is oriented parallel to the axial planes, developed either during, or after the culmination of the regional metamorphism. The main fold axes, which generally trend northeast, were refolded by west- to northwest-trending crossfolds. Although crossfolds could have formed simultaneously with the major folds, at least some of the crossfolding is associated with intrusions which were forcefully emplaced after the development of the major folds. Fold styles change with increasing grade of regional metamorphism and with the major rock types involved in the folding. The ductility (the ability of a rock to flow without fracture or faulting) of the metasediments and metavolcanics increases with increasing metamorphic grade, but in each of the metamorphic zones, the ductility of the carbonate metasediments and the calcareous metasandstone and metasiltstone is generally higher than the ductility of the clastic siliceous metasediments and the metavolcanics.

In southern Tudor Township, the major folds are the Millbridge and Jordan Creek Synclines which are separated in south-central Tudor Township by an anticline. In both synclines, because of flowage in the marbles, lineations defined by the plunge of minor folds commonly plunge in directions opposite to the plunge of the major folds. Both synclines plunge southwestwards, but the closure in clastic siliceous metasediments within the Millbridge Syncline in the southwest corner of Tudor Township indicates that in this area the syncline plunges east-northeast. The Millbridge Syncline extends for a short distance into the Tudor metavolcanics, but except for a minor synclinal buckle east of the southern part of the Glanmire Complex, and a minor anticline southwest of the Lingham Lake Complex, major structural closures are absent in this formation within the map-area.

In northern Tudor Township, between the Beaver Creek and Wadsworth intrusions, metasediments of the Dungannon and Vansickle formations were folded into a southwestern plunging syncline; pebbles in metaconglomerate of the Vansickle formation are flattened parallel to the axis of the syncline and plunge 65 to 70 degrees southwest.

In Limerick Township, there are six major folds: 1) the Murphy Corners Anticline; 2) the Robinson Lake Syncline; 3) the Urbach Lake Anticline; 4) the Bea Lake Syncline; 5) the Dixon Lake Syncline; and 6) the Egan Lake dome. The Murphy Corners and Urbach Lake Anticlines extend into Wollaston Township where they were first mapped by Hewitt (1962). Axial surfaces of these major folds dip west to northwest, and most of the folds plunge southwestward. The Murphy Corners Anticline, the Robinson Lake Syncline, and the Urbach Lake Anticline comprise the eastern half of the Ormsby dome which is bounded in the map-area by the Umfraville Gabbro, the Bea Lake Syncline, and the syncline between the Jocko Lake Complex and Limerick Lake. The Murphy Corners Anticline was intensely deformed by faulting and crossfolding both of which are related in part to the forceful emplacement of the Jocko Lake and Thanet Complexes.

In the eastern part of Limerick Township north of Limerick Lake, folds plunge northeastward and the west to northwest dips of axial surfaces are sufficiently shallow to produce overfolds. Tectonic transport of marble parallel to the axial surfaces of these overfolds probably caused the westward plunging mineral lineations found in relatively thin metagreywacke layers. In northeastern Limerick Township, the Egan Lake dome plunges southeast and is terminated near the Bea Lake Syncline. Farther to the northeast in Mayo Township, the dome plunges northeast and is terminated by a syncline which trends northeast between Mayo and Gin Lakes.

Faulting

In such a structurally complex terrane as the map-area, faulting probably occurred at various stages of the tectonic history. Several prominent lineaments, which are readily apparent on air photographs, coincide with structural features in the nearby rocks such as: 1) zones of shearing, mylonitization, brecciation, and complex contortion; 2) displacement of geological contacts; 3) prominent scarps; and 4) late calcite and quartz fissure veins. These lineaments, which are shown in the accompanying maps, are probably faults, most of which appear to be subvertical. Although many of these postulated faults branch and have variable orientations along their strike, most can be assigned to one of two major systems — a northeast system in which strike orientations range from north-northwest to east-northeast, and a northwest system in which strike orientations range from northwest to west.

Faults of the northeast system are at least partly concordant with structural trends in the rocks they traverse, and all are actually fault zones which range in width from a few feet to a few hundred feet. Rocks exposed within these fault zones are sheared, mylonitized, and complexly contorted; marble is invariably coarse-grained regardless of the grade of regional metamorphism, and rusty-weathering schists with or without associated quartz vein networks and discontinuous quartz veins are common. The amount of displacement along the faults is unknown, but most of the faults show left-handed offsets. Displacement of metamorphic isograds and of the intrusive rocks, and the common occurrence of mylonite in most of the faults show that they have undergone relatively late movements, but most of these faults probably originated at an early stage in the tectonic history of the area. The major faults of this system are: 1) Moira River Fault; 2) north to northeast-trending faults between the Lingham Lake and Tudor stocks; 3) faults along Beaver Creek west of the Glanmire Complex; 4) St. Ola Fault; 5) Limerick Lake Fault; 6) Twomile Lake Fault; and 7) Brinklow Fault. The Twomile Lake Fault branches into three subsidiary faults, one of which appears to truncate the Brinklow Fault. Within the various fault zones, outcrops are generally scarce, and the faults are marked by linear depressions which are commonly occupied by streams and swampy areas.

Within the northwest system of lineaments, outcrops are rare, and lithologic units are either not offset, or are only slightly offset; shear zones, complexly contorted zones, rusty-weathering schists, and coarse-grained marble such as found in the northeast system of lineaments, are absent. Nevertheless, breccias and slickensides are found in places along these lineaments, and the late calcite and quartz fissure veins are concentrated either within, or in the immediate vicinity of, these lineaments.

No outcrops were found in the five major northwest-trending lineaments in Limerick Township, but some of the lineaments have prominent scarps as high as 50 feet. Just northwest of Little Wadsworth Lake in the southeast corner of Limerick Township, a minor north-west trending fault contains a late calcite fissure vein. Numerous west to northwest-trending lineaments are present in Tudor Township. Outcrops are absent along the lineaments in northwestern Tudor, but, locally, they are marked by prominent scarps, and Macfarlane (1866) reported the presence of late calcite fissure veins in the vicinity of these lineaments. In eastern Tudor Township, a northwest-trending fault offsets the contact metamorphic aureole of the Lingham Lake Complex and is healed in part by quartz-carbonate fissure veins. In southern Tudor Township, all the lineaments of the northwest system have associated late calcite and quartz fissure veins, and one fault in the southeast corner of the township offsets the contact metamorphic aureole of the Gawley Creek stock.

ECONOMIC GEOLOGY

INTRODUCTION

The most common type of mineralization in the map-area is pyrite- and pyrrhotite-bearing, rusty-weathering schist zones in which the pyrite and pyrrhotite are present as disseminated grains and as locally developed massive streaks and lens-like bodies. Local concentrations of pyrite and, rarely, pyrrhotite are present in some of the carbonate metasediments. Gold, arsenic, copper, nickel, iron, titanium, lead, zinc, silver, bismuth, barite, and talc mineralization are found also within the map-area. Various types of marble present in the Dungannon formation are potential sources of terrazzo aggregate and building stone, and some middle greenschist facies, mafic and felsic metavolcanics, which have primary microtextures, would be suitable for roofing granules. Small sand and gravel deposits have been used for local road construction; marl is present in some of the lakes within marble-rich terranes. The base and precious metal mineralization, the industrially useful rocks and nonmetallic mineral occurrences, and descriptions of individual showings are discussed below.

Within the Bancroft–Madoc area and surrounding regions, a few general relationships of gold, arsenic, iron, nickel, copper, and of some industrially useful rocks and nonmetallic mineral occurrences to intrusive rocks and metamorphism have been pointed out by the author (Lumbers 1964). In the map-area, the distribution of the various mineral deposits is related to the stratigraphy, the intrusive rocks, the metamorphism, and the structure.

Prospecting and Mining Activity

Recorded interest in mineral occurrences within the map-area dates back to the 1850s, and some iron and lead ore and gold were produced in the late 1800s and early 1900s. Deposits of galena in the late calcite fissure veins were the first mineral occurrences to be exploited, and by 1869, 25 such occurrences within Tudor Township had undergone exploration (Vennor 1870). Galena was mined from a few of the veins (Vennor 1870), but total production was small. Iron, gold, and arsenopyrite deposits were discovered in the area between 1860 and 1880, but most of the exploration and development work on these deposits was carried out between 1880 and 1910. In 1901, 3,000 tons of iron ore were shipped from the St. Charles mine in Tudor Township (DeKalb 1901, p. 128), and in 1912 and 1913 a few tons of ilmenomagnetite concentrate were shipped from the Orton mine, Tudor Township, to the Tivani Steel Company of Belleville (Robinson 1922, p. 76). In 1906, a small quantity of gold was produced from the Craig mine in Tudor Township (Gibson 1907). In 1925, about five tons of galena concentrate were shipped from a late calcite fissure vein in southern Tudor Township (O.D.M. 1925, p. 165). Since 1925, no mineral production has been recorded from the area, but during the construction of Highway 62 in 1938 and 1939, the Campbell Construction Company Limited operated a marble quarry for road metal in lot 16, concession XVIII, Tudor Township (O.D.M. 1939, p. 66).

Limerick and Tudor Townships

Although most of the exploration and development work on the mineral deposits of the map-area was done during the latter half of the 1800s and the first quarter of the 1900s, in more recent years some attention has been given by the mineral industry to the gold, lead, and iron mineralization. A few new gold and arsenopyrite occurrences have been found, and since 1957, two deposits of copper and nickel have been found in mafic intrusions.

After the rise in the value of gold in 1934, the Craig gold mine underwent further exploration work at intervals between 1934 and 1936, but no gold production was reported (O.D.M. 1935, 1936). First discovered in the early 1900s, a gold- and arsenopyrite-bearing rusty schist zone in lot 1, concession I, Limerick Township and lot 33, concession XX, Grimsthorpe Township, was explored by trenches, pits, geophysical work, and diamond-drilling intermittently between the early 1950s and 1962.

Concentrations of galena in a late calcite fissure vein in lots 1 and 2, concession II, and lot 2, concession III, Limerick Township, were explored by Bouzan Gold Mines Limited from December, 1948 to March, 1949; trenching, stripping, and diamond-drilling were performed in the vein which was originally discovered in the late 1800s. Following the publication in 1950 of aeromagnetic data on the area, some of the old iron occurrences were re-examined and reconnaissance study of aeromagnetic anomalies was made by Harding (1951) and by Abraham (1951).

In 1957, Triana Exploration Limited, discovered copper and nickel mineralization in ultramafic rocks found in the southwest corner of the Lingham Lake Complex; stripping, trenching, and some diamond-drilling was carried out. This discovery led to renewed interest in the mafic intrusions of the area, and in June, 1961, Macassa Gold Mines Limited, discovered copper and nickel mineralization in metapyroxenite found in the northeastern corner of the Thanet Complex. Between September, 1961 and April, 1962, the deposit was explored by 23 diamond-drill holes.

In 1963, The International Nickel Company of Canada Limited owned the mineral and surface rights to about 27 percent of Tudor Township and to about 43 percent of Limerick Township; the distribution of these holdings is shown in Figure 5. According to the history of International Nickel by Thompson and Beasley (1960), these holdings were ceded to The International Nickel Co. of Canada Ltd. in 1916 by International Nickel Company which obtained the holdings by taking over The Anglo-American Iron Company and the Canadian Copper Company. These latter companies were formed by Samuel J. Ritchie and his associates who also built the railway that passes through the area. Some intermittent exploration work in the form of geological mapping, geophysical surveys, and diamond-drilling has been done by International Nickel on their holdings, but details of this work are not available.

Because most of the exploration and development work on mineral deposits within the map-area was done in the latter half of the 1800s and the early part of the 1900s, most of the workings are in poor condition for examination, and some of the old workings could not be found. Thus, the author has had to rely largely on the literature for descriptions of the old workings; unfortunately, data given in such descriptions are generally scanty, and the locations given for some of the old workings were found to be in error.

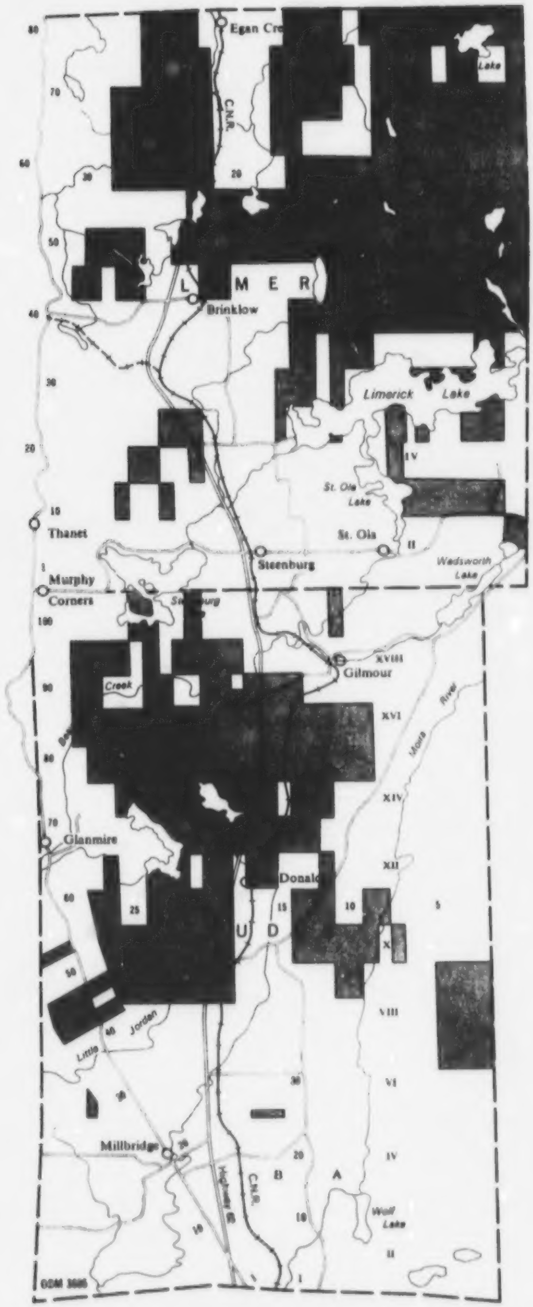
Egan Cr
C.N.R.
Lake
L M E R
Brinklow
Limerick Lake
St. Ola Lake
St. Ola
Thanet
Steenburg
Murphy Corners
Wadsworth Lake
XVIII
Gilmour
Creek
XVI
Moira River
XIV
Glanmire
XII
Donald
U D
Jordan
Little
VIII
VI
Millbridge
IV
B
A
Highway 62
C.N.R.
Wolf Lake
II
ODM 3686

Figure 5–Sketch map showing patented land owned by The International Nickel Company of Canada Limited, Limerick and Tudor Townships.

BASE AND PRECIOUS METAL MINERALIZATION

Rusty-Weathering Schists

In the map-area, much of the sulphide mineralization is found as disseminated pyrite and pyrrhotite in distinctive zones of rusty-weathering schists. These schists are fine-grained, intensely foliated rocks which on unweathered surfaces are light to dark-grey. Quartz and micaceous minerals are abundant in the schists, and in some of the schists the micaceous minerals are concentrated in thin layers, generally only a few millimetres thick; quartz veins and quartz vein networks are present locally. Most abundant in the clastic siliceous metasediments, the rusty schists, which are found in all the metasediments and metavolcanics of the area, are particularly common: 1) in north- to northeast-trending fault zones; 2) in the vicinity of the mafic intrusions; 3) at contacts of metavolcanic units; and 4) in intensely deformed clastic siliceous metasediments in eastern Limerick Township where overfolds formed in rocks of the Dungannon and Vansickle formations. The main rusty schist zones are shown on Maps 2167 and 2168 (back pocket).

Rusty schist zones are found throughout the Bancroft–Madoc area (Adams 1895, p. 9j-15j; Adams and Barlow 1910, p. 185-190; Lumbers 1964, Figure 7; Lumbers 1967a) particularly in areas of intense deformation, within contact metamorphic aureoles, and in clastic siliceous metasediments at the margins of metavolcanic units. The author concludes that some rusty schists are post-metamorphic hydrothermal replacements, others may represent tuffaceous iron sulphide-bearing sediments or black shales, and still others could be regionally metamorphosed sedimentary and volcanic rocks which were altered initially by fumarolic activity during volcanism. The rusty schist zones appear to be more numerous in the almandine amphibolite facies terrane than in the greenschist facies terrane where they are found mainly in contact metamorphic aureoles and in shear zones in metavolcanics. A few of the rusty schist zones have been mined in the past for their pyrite content, and some of the zones in sheared, greenschist facies metavolcanics have gold and arsenopyrite mineralization in associated quartz veins. Most of the rusty schists in the map-area have only disseminated pyrite and pyrrhotite; one rusty schist zone in sheared greenschist facies metavolcanics has gold and arsenopyrite mineralization in associated quartz veins (see "McMurray Occurrence" section).

Within the Bancroft–Madoc area, the mineralogy of the rusty schists has not been studied in detail, but within the map-area, 22 rusty schist specimens collected from both metavolcanic and metasedimentary units in all the metamorphic zones were studied by x-ray diffraction and in thin section. The results of these studies show:

1. Rusty schists in the greenschist facies terrane consist largely of quartz, muscovite, chlorite, and biotite. Minor minerals are epidote, plagioclase, calcite, graphite, potassic feldspar, and zircon.
2. Rusty schists in the almandine amphibolite facies terrane consist largely of quartz, muscovite, potassic feldspar, and biotite. Minor minerals are plagioclase, calcite, chlorite, garnet, graphite, sphene, epidote, and zircon.

3. Rusty schists from both metavolcanic and metasedimentary units have similar mineral assemblages, but rusty schists from metavolcanic units are generally rich in ferromagnesian minerals and poor in feldspar.

4. Pyrrhotite and pyrite are the main opaque minerals, but some rusty schists contain traces of magnetite, sphalerite, and chalcopyrite, particularly in association with metavolcanics.

5. The relative quantities of pyrite and pyrrhotite vary widely from one rusty schist zone to another, but the pyrite and pyrrhotite content generally ranges between 5 and 10 percent. Massive pyrrhotite and pyrite as narrow veinlets and lens-like bodies are present locally in most of the rusty schist zones and are particularly abundant in the following zones:
   a) West of the Lingham Lake Complex in lots 9 and 10, concessions V, VI, and VII, Tudor Township.
   b) In lots 16 to 18, concession IX and lots 15 and 16, concession X, Tudor Township.
   c) Within the contact metamorphic aureole of the Tudor Gabbro, just west of the railway in lots 17 and 18, concession X, Tudor Township.
   d) In the north half of lots 18 and 19, concession VI, Limerick Township.
   e) In the southwest corner of lot 19, concession VII, Limerick Township. (A small pit about 5 feet square and 3 feet deep was put down in this zone, and a grab sample of rusty schist collected by the author from the pit gave upon assay 0.46 percent zinc.)
   f) In the central part of lots 29 and 30, concession VIII, Limerick Township. (In lot 30, a small pit 8 feet long, 4 feet wide, and 3 feet deep was put down in this zone, and a grab sample of rusty schist collected by the author from the pit gave upon assay 0.21 percent zinc.)
   g) In the south half of lot 29, concession IX, Limerick Township.
   h) South of Dixon Lake in lots 3 and 4, concession X, Limerick Township.

6. Graphite is generally absent in rusty schists that do not contain calcite and abundant pyrite and pyrrhotite. The most graphitic rusty schists are found in carbonate metasediments and contain numerous veinlets and lensoid bodies of massive pyrite, and such rocks could be more intensely altered phases of the metamorphosed black shales described in connection with the felsic pyroclastic rocks.

In both the metasediments and the metavolcanics, the rusty schists commonly form well defined zones which, in general, are concordant with the structural trends in the enclosing rocks. Many of the rusty schist zones are comparatively thin and persistent along the strike; thin rusty schist units, some of which are in fault zones, can be traced for more than 2 miles. Rusty schist zones in sheared metavolcanics commonly contain partly altered remnants of the metavolcanics in which garnet is found in the relic metavolcanic patches within the rusty schist zones and in the wallrock metavolcanics. Rusty schist zones in the metasediments commonly transgress primary structures such as bedding. In the clastic siliceous metasediments, the rusty schist zones commonly have gradational contacts; irregularly shaped rusty patches and rusty-weathering, dike-like zones of alteration, which are mineralogically similar to the rusty schists, are common in the clastic siliceous metasediments near main zones of rusty schist. In contact metamorphic aureoles, some rusty schist zones can be traced into adjacent intrusive rocks. Quartz veins and quartz vein networks within rusty schist zones are accompanied commonly by streaks of massive pyrite and pyrrhotite mineralization in the adjacent rusty schist.

Table 8 CHEMICAL ANALYSES OF RUSTY SCHISTS FROM TUDOR TOWNSHIP (AFTER MILLER AND KNIGHT, 1913, P. 85)

	RUSTY SCHIST, ONE MILE EAST OF GILMOUR	RUSTY SCHIST, SECOND RAILWAY CUT SOUTH OF GILMOUR STATION
SiO_2	63.12	73.78
Al_2O_3	3.94	9.44
FeO	4.04	4.93
Fe_2O_3	....	1.03
MgO	2.65	2.37
CaO	4.99	1.09
Na_2O	0.73	2.72
K_2O	1.30	1.51
H_2O	1.33	2.57
CO_2	4.67	0.63
FeS_2	13.32	....
Total	100.09	100.07

Chemical analyses of two rusty schists from northeastern Tudor Township are reproduced in Table 8. No petrographic data are available for these rocks, but both are from rusty schist zones in metavolcanics, and in the schists of these zones, biotite, chlorite, and feldspar are prominent constituents. Because some of the rusty schists appear to be of sedimentary origin, and because sedimentary rocks generally contain more trace amounts of Ni than Co (Krauskopf 1955), three rusty schist specimens from metavolcanic units and six from metasedimentary units were analysed spectrographically by the Laboratory Branch, Ontario Department of Mines, for major trace elements (Table 9). For comparison, 11 feldspathic metagreywacke specimens from various parts of the map-area and 3 porphyroblastic hornblende metasediment specimens from Limerick Township also were analysed, and because variations among the analyses of both these metasedimentary types are small, only the averages are shown in Table 9. With increasing grade of regional metamorphism, no major differences in trace element content of each of the three rock types could be detected. Moreover, the trace element contents of the metagreywackes and the porphyroblastic hornblende metasediments are similar to those of sandstones given by Krauskopf (1955).

Relative to the metasediments of the map-area, most of the rusty schists contain more Cu, Ni, Mo, and B, less Mn, and much higher ratios of Ni:Co. Furthermore, their trace elements lie within the range reported by Krauskopf (1955) for black shales (Table 9). Although the trace element data suggest a sedimentary origin, the fact that some of the rusty schists contain gold and silver concentrations and sphalerite and chalcopyrite, suggests juvenile contributions, or possibly a hydrothermal origin. Discordance of some of the rusty schist units

Table 9 SPECTROGRAPHIC ANALYSES OF RUSTY SCHISTS AND METASEDIMENTS FROM TUDOR AND LIMERICK TOWNSHIPS (Ti and Mn expressed in percent; other elements are in parts per million)

Specimen No.	Ti	Mn	Cu	Ni	Co	Pb	Zn	Cr	V	Zr	Mo	Ag	B
RUSTY SCHISTS FROM METAVOLCANIC UNITS													
61-L-111	0.3	0.02	60	70	8	10	70	15	40	170	10	1	40
61-L-392	0.5	0.02	20	5	5	10	50	15	70	140	5	<1	10
62-L-214	1.5	0.02	80	60	15	15	70	300	300	200	5	1	50
RUSTY SCHISTS FROM METASEDIMENTARY UNITS													
61-L-117	0.3	0.01	50	70	10	15	70	15	80	140	10	3	60
61-L-118	0.2	0.02	200	80	5	10	70	20	60	80	10	<1	100
62-L-4	0.3	0.03	50	30	15	10	100	15	80	60	5	1	60
62-L-6	0.4	0.04	90	30	8	20	100	15	60	140	20	1	30
62-L-45	0.3	0.04	400	70	10	10	500	20	100	200	10	1	15
62-L-261	0.4	0.09	60	30	10	10	50	15	30	200	5	1	30
AVERAGE OF ELEVEN FELDSPATHIC METAGREYWACKE SPECIMENS													
	0.4	0.05	45	6	8	10	70	17	50	140	5	<1	10
AVERAGE OF THREE PORPHYROBLASTIC HORNBLENDE METASEDIMENT SPECIMENS													
	0.6	0.08	40	17	17	10	90	25	130	210	<5	<1	10
AVERAGE SANDSTONE (KRAUSKOPF 1955)													
	....	....	10-40	2-10?	1-10?	10-40?	5-20	10-100?	10-60	....	0.1-1?	0.4?	....
AVERAGE BLACK SHALE (KRAUSKOPF 1955)													
	....	....	20-300	20-300	5-50	20-400	100-1000	10-500	50-2000	10-20?	10-3000	5-50	....

also could be explained by a hydrothermal origin or by minor, late-stage, post-metamorphic mobilization. Available data are, at best, sufficient to outline only a few possible hypotheses of origin, and much more petrographic and chemical data are needed.

Other Pyrite and Pyrrhotite Mineralization

In the fine-grained, and fine- to medium-grained marbles, euhedral pyrite crystals and massive pyrite streaks are common along joints, and, in places, as much as ten percent pyrite is disseminated as fine- to medium-grained crystals in crude layers parallel to the bedding in the marbles.

One-quarter mile south of Brett Lake, and about 200 feet west of the boundary between Tudor and Lake Townships, a massive 8-inch wide, pyrite and pyrrhotite vein in fine-grained marble is exposed in the northwest corner of a small pit, 8 feet square and 6 feet deep. A grab sample collected from the vein by the author gave upon analysis only trace amounts of gold, silver, copper, and nickel.

Gold and Arsenic

Fourteen workings were found in the map-area which were opened in order to examine gold and arsenopyrite mineralization. Willimott (1885, p. 12L) and Thomson (1943, p. 33) mentioned, but did not examine, two additional occurrences of gold mineralization which could not be found by the author. Of the 14 workings found, reliable data concerning exploration work and mineralization could be obtained for only the McMurray occurrence. Assays of grab samples collected by the author from the 14 workings show that 4 contain more than trace amounts of gold: 1) the Quinlan Lake deposit; 2) the Craig deposit; 3) a deposit in lot 5, concession XIII, Tudor Township; and 4) the McMurray deposit. These four deposits and all the arsenopyrite mineralization are confined to the greenschist facies terrane. Except for arsenopyrite in the McMurray deposit, which is in a rusty schist zone, the arsenopyrite mineralization is found either in potassic rhyolite units, or in the vicinity of the Lingham Lake Complex. With the exception of minor, disseminated arsenopyrite in some potassic rhyolites within the greenschist facies terrane, the gold and arsenopyrite mineralization is restricted to quartz veins.

Several generations of quartz veins are present in the map-area. Quartz veins may have formed either during the accumulation of the metasedimentary-metavolcanic sequence, or during the metamorphism of these rocks; some quartz veins are late phases of intrusions, whereas others are associated with the late calcite fissure veins. Quartz veins are particularly common near contacts between felsic and mafic metavolcanics, within contact metamorphic aureoles in the greenschist facies terrane, and in the rusty schist zones. Most of the quartz veins are either barren of visible mineralization, or contain only traces of pyrite, pyrrhotite, and chalcopyrite. Tourmaline is abundant locally in quartz veins associated with albite granite complexes and with the late calcite fissure veins. Quartz veins in almandine amphibolite facies metavolcanics contain only rare traces of gold and silver, whereas quartz veins in greenschist facies metavolcanics and in rusty schist zones commonly give upon assay traces of gold and silver. The widest and most persistent quartz veins are found in contact metamorphic aureoles in the greenschist facies terrane; the quartz vein at the Craig deposit, which lies within the Lingham Lake Complex contact metamorphic aureole, is the largest found in the map-area and is the only auriferous vein in the area from which gold production is reported.

DESCRIPTION OF DEPOSITS

Craig Mine

The Craig mine, which is in the south halves of lots 4 and 5, concession III, Tudor Township (No. 17 on Map 2168), was discovered in the late 1800s (Slaght 1898; Adams and Barlow 1910, p. 345). Between 1905 and 1906 bullion valued at $5,760 was produced from 1,850 tons of ore (Young 1936, p. 14). Except for some development work performed between 1934 and 1936, the mine has been idle since 1907, and all buildings and equipment have been removed.

Both surface and subsurface workings are present at the mine, but when the author visited the property in 1961, only three mine dumps and surface workings in the form of two partly filled trenches and two shaft openings were available for examination. Judging from the surface workings, the available outcrops, and the broken rock of the three dumps, the mineralization is in a prominent northwest-trending quartz vein which, locally, passes into zones of closely spaced, *en échelon* quartz veins. On the surface, the vein, which ranges in width from ½ to 6 feet, can be traced at intervals for 990 feet and is in contact metamorphosed mafic metavolcanics of the Tudor metavolcanics which form part of the aureole of the Lingham Lake Complex; the vein was traced to within 20 feet of the southern contact of the complex. In the two trenches, slickensides are present in the wallrock metavolcanics, and the quartz vein is sheared locally; where massive the quartz is generally white, but where sheared the quartz is generally grey to bluish-grey. Blocks of altered metavolcanics are present in vein material on the three mine dumps. These features suggest that the vein is a fissure filling; 860 feet due west of the vein in lot 5, concession III, a northwest-trending fault zone was found in the metavolcanics in which discontinuous quartz veins and quartz vein networks are developed locally. These veins rarely contain sparsely disseminated pyrite, pyrrhotite, and chalcopyrite, and a grab sample of one mineralized vein collected by the author gave upon assay traces of gold and silver.

Recorded data concerning development work done, geological relationships, the character of the mineralization, and dimensions and grade of the mineralized zone are scanty and, in part, conflicting. The earliest reference to development work is made by Slaght (1898, p. 92) who states:

> Gold was discovered on the property several years ago, and the owners opened the mine by stripping the vein for 100 feet and sinking two pits of 10 feet each. The ore was treated at the Bannockburn mill, yielding $4 per ton [gold at $20.67 per ounce]. The mine remained idle for several years, but late in 1896 a company of Toronto capitalists took an option on it for six months, when the property reverted to the original owners and has been lying idle

ever since. During this period a shaft was sunk 100 feet, showing a width of vein at the bottom of eight feet. Several small test lots of ore were shipped for treatment, but the result does not appear to have encouraged further operations.

Following its reopening in 1904 by the Craig Gold Mining and Reduction Company of Newark, New Jersey, Corkill (1905, p. 76) visited the mine and describes the development work as follows:

> Two shafts have been sunk at a distance of about 400 feet apart, the south shaft to a depth of 110 feet. At a depth of 60 feet a level has been run, the north drift being 280 feet and the south drift 40 feet in length. Stoping is carried on in both drifts. In the north shaft, which has been sunk to a depth of 110 feet, a drift has been run south a distance of 80 feet from the 60-foot level.

Development work done in 1906 is described by Corkill (1906, p. 89) as follows:

> No. 1 shaft on which all work is being carried on at present, is 150 feet in depth. The first level is at a depth of 60 feet, and a drift some 400 feet in length has been run northwest from this level to connect with No. 2 shaft. About 30 feet northwest of the shaft the ore has been stoped out for a distance of 75 feet along the vein and 30 feet in height. The drift southeast on this level is 50 feet in length, and has been stoped out for a height of 30 feet.
>
> On the second level, which is at a depth of 150 feet, drifts have been run in both directions on the vein for about 25 feet. Timber is cut for a new skip and ladder-way in the shaft. No. 2 shaft northwest of No. 1 shaft and connected with it, is 110 feet deep, with no drifting except on the 60-foot level.
>
> The mill was completed last year and about 2,000 tons of ore milled. The plant consists of a Merrall mill with two batteries of three stamps each and two Wilfley tables. The concentrates from the ore contain in addition to the gold, from 1 to 1.5 per cent. of copper. None of the concentrates have been shipped as yet, but owing to the erection of a copper smelter at Eldorado [village in Madoc Township] there should be no difficulty in securing a market, since they would be a desirable aid as a flux in smelting the copper ores there.

In 1934, when the mine was taken over by Craig Gold Mines Limited, the two shafts on the property were 210 and 165 feet deep, and 1,800 feet of lateral work existed (O.D.M. 1935, p. 86). From 1934 to 1937, according to the available records (O.D.M. 1936, p. 98; 1937, p. 120-121), the No. 1 shaft was sunk to a depth of 245 feet, and stations were cut at 50, 125, and 225 feet. About 350 feet of drifting was done on the 50-foot level and 910 feet on the 225-foot level. No. 2 shaft, whose depth is reported to be 200 feet, was cleaned out, and some exploration work was done on the 100-foot level. During 1936 about 5,200 tons of rock were hoisted through the No. 1 shaft.

It is not clear from the available records whether or not the No. 1 and No. 2 shafts referred to by Corkill correspond to the No. 1 and No. 2 shafts referred to in the records of work done in the 1930s. The depth of both shafts does not appear to be precisely known and, according to the earliest records, the first level in the underground workings is at 60 feet rather than 50 feet. On the surface, the author found the two shafts to be about 270 feet apart, rather than 400 feet apart as stated by Corkill (1905, p. 76). The northwestern end of the vein is exposed in a trench which is partly filled by debris and is about 250 feet long, as much as 9 feet wide, and at least 5 feet deep. A second trench, which is about 200 feet southeast of the most southerly of the three mine dumps, is also partly filled by debris and is 20 feet long, 5 feet wide, and about 4 feet deep.

A grab sample collected by the author from the vein exposed in the second trench gave upon assay 0.65 ounces gold per ton, 0.41 ounces silver per ton, and 0.76 percent copper; sparsely disseminated pyrite and about 10 percent chalcopyrite were visible in the specimen. Vein material on the three mine dumps commonly contains disseminated pyrite, pyrrhotite, and chalcopyrite, and a grab sample containing about 5 percent disseminated chalcopyrite and rare pyrite collected by the author from the dump southwest of the vein gave upon assay 0.17 percent copper, 0.04 ounces gold per ton, and a trace of silver. A grab sample, containing sparsely disseminated pyrite and less than 10 percent chalcopyrite collected by the author from the vein exposed near the most southerly of the two shafts gave upon assay 0.26 percent copper, 0.20 ounces gold per ton, and a trace of silver. A grab sample collected by the author from the most southerly of the three mine dumps and containing less than 15 percent disseminated pyrite, pyrrhotite and chalcopyrite, gave upon assay 0.48 percent copper, 0.11 ounces gold per ton, and 1.95 ounces silver per ton. No mention is made in the available records of the silver mineralization at the Craig mine.

Thomson (1943, p. 33) collected specimens for assay from the Craig mine and he reports as follows:

> A selected grab sample of the best looking quartz around No. 1 shaft was taken by the writer and assayed 0.03 ounces gold per ton. A similar sample from the dump at No. 2 shaft assayed 0.49 ounces per ton.

McMurray Occurrence

In 1962, V. A. McMurray of Gilmour held an option on the mineral rights to lot 1, concession I, Limerick Township (No. 4 on Map 2167), and owned the surface and mineral rights to lot 33, concession XX, Grimsthorpe Township.

Gold and arsenopyrite mineralization associated with quartz veins locally developed in a rusty schist zone have been explored by seven pits and four trenches as shown in Figure 6. Most of the pits (Nos. 3 to 7) were opened by the Wadsworth Lake Mining Company during the early 1900s. In the early 1950s Stratmat Mines Limited, did geophysical work and drilled a few holes. From 1958 to 1960, Mr. McMurray sank two pits (Nos. 1 and 2) and did some stripping and diamond-drilling in the northern part of the rusty schist zone. During the author's visit to the property in September, 1962, Macassa Gold Mines Limited completed a 310-foot diamond-drill hole in the rusty schist zone.

The general geology in the immediate vicinity of the McMurray occurrence is shown in Figure 6 which was prepared by the author in 1962. The north-northeast-trending rusty schist zone, which partly follows the contact of the Tudor metavolcanics and the Oak Lake formation, can be traced at intervals for about 3,050 feet from the south half of lot 1, concession I, Limerick Township, to the central part of lot 33, concession XX, Grimsthorpe Township. Numerous, partly altered remnants of both felsic and mafic metavolcanics are present within the rusty schist zone; altered mafic metavolcanic remnants commonly contain garnet porphyroblasts. Partly altered metatuff, which is present in the central part of the rusty schist zone (Figure 6) may be continuous with metatuff of the Oak Lake formation exposed across a swampy area farther to the northeast in the north half of lot 1, concession I, Limerick Township. Irregularly shaped quartz veins, generally less than a foot wide, and quartz vein networks are found locally in the rusty schist zone, and the largest veins seen by the author are exposed in the various pits. The rusty schist contains 5 to 10 percent disseminated pyrite and pyrrhotite and, locally, massive stringers and lens-like

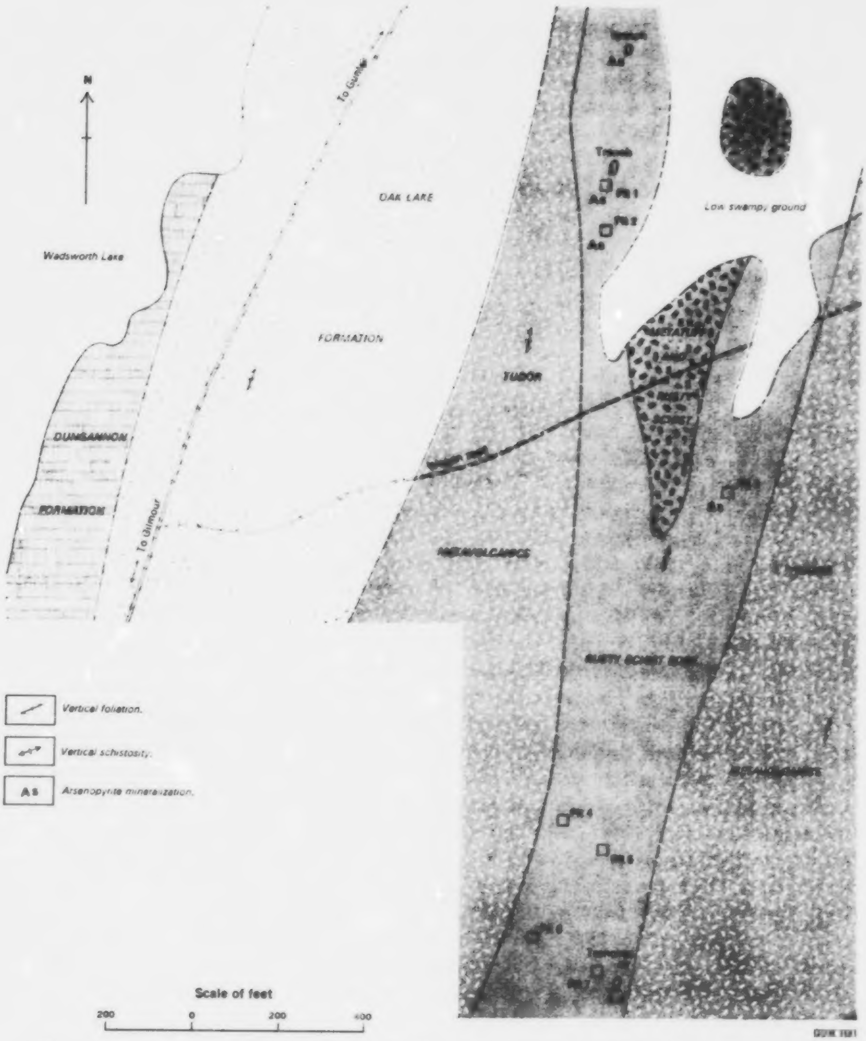
N
To Gunter
To Gilmour
Wadsworth Lake
DUNGANNON
FORMATION
OAK LAKE
FORMATION
TUDOR
METAVOLCANICS
Low swampy ground
Trench
As
Pit 1
Pit 2
Pit 3
RUSTY SCHIST ZONE
Pit 4
Pit 5
Pit 6
Pit 7
Trench
Vertical foliation.
Vertical schistosity.
As
Arsenopyrite mineralization.
Scale of feet
200
0
200
400

Figure 6–Sketch map of the geology and workings, McMurray occurrence, Limerick Township.

bodies of pyrite, pyrrhotite, and minor chalcopyrite. Most of the gold and arsenopyrite mineralization appears to be in the vicinity of pit Nos. 1 and 2 (Figure 6) which constitute the main showing. Sparsely disseminated arsenopyrite is present in rusty schists at the two trenches north of pit No. 1, at pit No. 3, and in the trench due east of pit No. 7. Grab samples collected by the author from quartz veins exposed in pit Nos. 3, 4, 5, and 6 showed upon assay traces of gold and silver. All these quartz veins are either barren of visible mineralization, or they contain only traces of pyrite. Grab samples of arsenopyrite-bearing rusty schist collected by the author at pit No. 3 and at the trench due east of pit No. 7 gave upon assay traces of gold and silver.

At pit No. 1, which is 7 feet long, 5 feet wide, and as much as 6 feet deep, sheared and intensely altered mafic metavolcanics are cut by quartz vein networks in which the individual veins range in width from 1 inch to 6 inches. Garnet crystals as much as ¼ inch in diameter and arsenopyrite crystals as much as ½ inch in diameter are disseminated in the altered mafic metavolcanics, and as much as 30 percent disseminated arsenopyrite is present in the altered metavolcanics next to the quartz veins. Some arsenopyrite is present in the quartz veins, but most of the veins are barren of visible mineralization. In rusty schist exposed in a stripped area south of pit No. 1, at pit No. 2, and at the trench north of pit No. 1, sparsely disseminated magnetite and chalcopyrite are present locally, and remnants of relatively unaltered mafic metavolcanics are found indicating that at least part of the rusty schist zone was originally mafic metavolcanics. Grab samples of the best mineralized altered metavolcanics collected by the author from pit No. 1 showed upon assay traces of gold and silver.

Through the courtesy of Mr. McMurray, nine selected specimens of split drill core from a 123-foot hole drilled northeastward, 100 feet south of pit No. 1, were collected by the author. Six of these specimens were 2-inch to 3-inch lengths of quartz veins sparsely mineralized with pyrite, chalcopyrite, and magnetite, and, rarely, with pyrrhotite and arsenopyrite. Upon assay, three of the six specimens showed no gold or silver, and the other three showed traces of gold and silver. Near the bottom of the hole, a 3½-foot section containing abundant arsenopyrite mineralization in quartz veins and intensely silicified metavolcanics was collected and assayed in three sections with the following results: 1) a 1½-foot section composed mainly of quartz with minor amounts of silicified metavolcanics and containing 10 to 40 percent disseminated to massive arsenopyrite gave upon assay 0.27 ounces gold per ton and a trace of silver; 2) a 1-foot section composed of quartz with as much as 55 percent disseminated to massive arsenopyrite gave upon assay 0.14 ounces gold per ton and a trace of silver; and 3) a 1-foot section of intensely sheared and silicified mafic metavolcanics with 5 to 10 percent disseminated arsenopyrite and sparsely disseminated magnetite, pyrrhotite, pyrite, and chalcopyrite gave upon assay 0.06 ounce gold per ton and a trace of silver. The results of this sampling suggest that the gold mineralization is associated with arsenopyrite mineralization in quartz veins and in silicified metavolcanics. Nevertheless, the author could find no native gold or gold-bearing minerals in polished sections of massive arsenopyrite from auriferous, quartz-rich material in the drill core.

Quinlan Lake Occurrence

In the south half of lot 2, concession II, Tudor Township, about 500 feet north of the north-central shore of Quinlan Lake (No. 24 on Map 2168), a northeast-trending quartz vein as much as 10 feet wide has been partly stripped. The vein which is in middle greenschist facies mafic metavolcanics, contains some disseminated arsenopyrite, a minor amount of pyrite, and, locally, tourmaline. A grab sample collected from the vein by the author gave upon assay 0.08 ounce gold per ton and a trace of silver.

Lot 5, Concession XIII, Tudor Township

In the north half of lot 5, concession XIII, Tudor Township (No. 9 on Map 2168), an open-cut, about 8 feet long, 5 feet wide, and 4 feet deep, in a potassic rhyolite unit exposes a quartz vein about 2 feet wide. The vein, which is best exposed on the north face of the cut, contains minor disseminated arsenopyrite, and, in the rhyolite next to the vein, a few massive stringers of arsenopyrite as much as an eighth of an inch wide are present locally. A grab sample of the vein material collected by the author gave upon assay 0.01 ounce gold per ton and a trace of silver. A grab sample of massive arsenopyrite from the rhyolite gave upon assay 0.03 ounce gold per ton and a trace of silver.

Lot 4, Concession I, Tudor Township

Two pits were opened to examine quartz veins in middle greenschist facies mafic metavolcanics in the southern half of lot 4, concession I, Tudor Township (No. 2 on Map 2168). In the most northerly of the two pits, a grab sample collected by the author from a 3-foot wide quartz vein, which is barren of visible mineralization, showed upon assay no gold or silver. At the most southerly pit, a zone about 10 feet wide contains numerous quartz-carbonate veins which trend parallel to the foliation in the host metavolcanics. The quartz in the veins is iron-stained, but no mineralization was found either in the veins, or in the metavolcanics. A grab sample of the vein material collected by the author showed upon assay no gold or silver.

Arsenopyrite in the Lingham Lake Complex

Two occurrences of arsenopyrite mineralization in quartz veins associated with trondhjemite dikes are present within the Lingham Lake Complex, Tudor Township. One of the veins in lot 1, concession VI, Tudor Township (No. 6 on Map 2168), is exposed in a shallow pit and is barren of mineralization; sparsely disseminated arsenopyrite was found in broken pieces of the vein found near the pit, and a grab sample of one of these mineralized pieces collected by the author showed upon assay no gold or silver. The second vein, in lot 1, concession X, Tudor Township (No. 7 on Map 2168), contains less than 10 percent disseminated arsenopyrite and pyrite; a grab sample collected from the vein by the author gave upon assay traces of gold and silver.

Lot 11, Concession XIII, Tudor Township

In lot 11, concession XIII, Tudor Township (No. 10 on Map 2168), about 260 feet south of the power line and 230 feet west of the Snow Road, five pits which are now largely filled by debris, were excavated in interlayered, middle greenschist facies felsic and mafic metavolcanics. At the largest pit, which is 20 feet long, 5 feet wide, and at least 15 feet deep, a quartz-carbonate vein, about 1 foot wide, and numerous quartz stringers are exposed; just to the west of the pit much quartz-carbonate vein material is present on an old dump. Only minor disseminated pyrite was seen in both the veins in the pit and the vein material on the dump. A grab sample collected by the author from the vein in the pit showed upon assay traces of gold and silver.

Lot 4, Concession XIV, Tudor Township

About 350 feet south of the power line in lot 4, concession XIV, Tudor Township (No. 12 on Map 2168), four shallow trenches were excavated in mylonitized, porphyritic, potassic rhyolite which contains as much as 10 percent disseminated arsenopyrite and, locally, sparsely disseminated pyrite and chalcopyrite. A grab sample of the best mineralized rhyolite collected by the author gave upon assay traces of gold, copper, and silver.

Lot 5, Concession XV, Tudor Township

On the north side of a small beaver pond in the south half of lot 5, concession XV, Tudor Township (No. 15 on Map 2168), a 1-foot wide quartz vein is exposed in a shallow pit about 7 feet long, 2 feet wide, and 4 feet deep. The quartz vein, which is in middle greenschist facies metatuff, contains sparsely disseminated pyrite, and a grab sample collected from the vein by the author showed upon assay no gold or silver.

Quartz Veins in the Glanmire Complex

Quartz veins rich in tourmaline are abundant locally in the Glanmire Complex, Tudor Township, especially in the southern intrusive centre. Near the west-central boundary of lot 25, concession XII, Tudor Township (No. 8 on Map 2168), a shallow pit exposes a 3-foot wide quartz vein barren of visible mineralization. A grab sample of the quartz vein collected by the author showed upon assay no gold or silver. In the north half of lot 26, concession XIII, Tudor Township (No. 11 on Map 2168), a 10-foot wide quartz vein is exposed in a pit about 9 feet long, 5 feet wide, and about 10 feet deep. The bottom of the pit was filled with water when the author visited the occurrence in June, 1961. Tourmaline and sparsely disseminated pyrite mineralization are present in the vein, and a grab sample collected by the author showed upon assay traces of gold and silver.

Lot 9, Concession VII, Limerick Township

A small pit near the north shore of Limerick Lake in lot 9, concession VII, Limerick Township (No. 2 on Map 2167), was largely filled when the author visited this occurrence in July, 1962. Adams and Barlow (1910, p. 346) refer to this prospect as the Higman mine, and samples of quartz from the pit collected by Adams and Barlow showed upon assay no gold and 0.175 ounce silver per ton.

Other Occurrences

Willimott (1885, p. 12L) describes an occurrence as follows:

> This property [Sheppard's Gold Mine] is mentioned on the authority of Mr. Sheppard. It is said to be on lot 12, Hastings road, in the township of Tudor. A vein of quartz, eleven feet thick in granite, has been traced for about 200 feet, the whole of which distance, distinct traces and colours of gold were met with. A pit has been sunk to the depth of fifteen feet; specimens taken from the bottom of the pit are said, by Mr. Sheppard, to have assayed as high as 5 ounces of gold to the ton.

Thomson (1943, p. 33) describes an occurrence as follows:

> According to a private report to the International Nickel Company in 1908, there is a quartz vein on lot 7, concession X, Tudor township, that carries a little arsenopyrite and about $2.00 per ton in gold [gold at $20.67 per ounce]. The vein strikes in a north-south direction and cuts through gneiss and diorite.

The author was unable to locate the above occurrences.

Copper and Nickel

With the exception of minor amounts of chalcopyrite in the rusty schist zones, in contact metasomatic iron deposits (see section on "Iron and Titanium"), and in quartz veins, concentrations of copper and nickel are mainly in ultramafic units of the Thanet and Lingham Lake Complexes. Ultramafic and mafic-rich rocks of the Tudor and Umfraville Gabbros have associated concentrations of iron-titanium oxide minerals, but concentrations of sulphide minerals are unknown. In the Jocko Lake Complex, whose gabbro has many petrographic and chemical features in common with uralitized gabbro of the Thanet Complex, metapyroxenite dikes are common and, in places, such as in lot 20, concession IX, Limerick Township, these dikes contain as much as 10 percent disseminated pyrite, pyrrhotite, and chalcopyrite. Acccessory sulphide minerals are least abundant in the Umfraville Gabbro which is the only mafic intrusion that has a potassia differentiation trend.

Compared with other mafic intrusions in the area, the Thanet and Lingham Lake Complexes contain much more quartz-bearing diorite and tonalite, and, perhaps, greater concentrations of ultramafic rocks. Analysed gabbro of the Thanet Complex (Table 7) has a lower ferric to ferrous iron ratio than analysed gabbros from the Umfraville, Jocko Lake, and Tudor intrusions.

Magnetic opaque fractions from tonalite, uralitized diorite, uralitized gabbro, and unaltered gabbro of the Thanet Complex were analysed spectrographically by the Laboratory Branch, Ontario Department of Mines, for trace amounts of titanium, vanadium, chromium, manganese, cobalt, and nickel. Each fraction consisted of at least 90 percent iron-titanium oxide minerals, and pyrrhotite was the main impurity. Similar magnetic opaque fractions from major phases of the Umfraville, Jocko Lake, Tudor, and Beaver Creek intrusions were also analysed, and the results are given in Table 10. Except for the unaltered gabbro, which is a relatively late phase, the magnetic opaque fractions from the major intrusive units of the Thanet Complex are markedly richer in cobalt and nickel than the analysed magnetic opaque fractions from the other rocks.

Table 10 SPECTROGRAPHIC ANALYSES OF MAGNETIC OPAQUE FRACTIONS FROM ROCKS OF THE THANET, JOCKO LAKE, TUDOR, UMFRAVILLE, AND BEAVER CREEK INTRUSIONS (Values of 0.01% and higher determined quantitatively and are accurate to within ± 10% Values below 0.01% may be in error up to 100% of amount)

Intrusion and rock type	%Ti	%V	%Cr	%Mn	%Co	%Ni
Thanet Complex						
Uralitized gabbro	0.13	0.07	0.06	0.18	0.09	0.64
Uralitized diorite[1]	0.2	0.05	0.07	0.08	0.02	0.1
Tonalite	0.17	0.03	0.13	0.23	0.07	0.18
Unaltered gabbro	3.6	0.51	0.19	0.12	0.01	0.02
Jocko Lake Complex						
Gabbro	2.0	0.20	0.08	0.10	0.003	0.02
Diorite	0.85	0.26	0.01	0.05	0.01	0.02
Tudor Gabbro						
Gabbro	3.9	0.42	0.22	0.25	0.005	0.02
Diorite	3.5	0.64	0.50	0.22	0.008	0.03
Umfraville Gabbro						
Olivine gabbro	0.80	0.23	0.87	0.10	0.005	0.06
Gabbro	0.20	0.31	0.28	0.04	0.005	0.02
Anorthositic gabbro	0.19	0.22	0.06	0.04	0.003	0.02
Syenite	0.87	0.06	<0.005	0.05	0.0005	0.002
Beaver Creek Complex						
Medium-grained albite granite	0.44	0.03	0.01	0.03	0.0005	0.003
Medium-grained albite syenite	0.44	0.04	0.04	0.04	0.001	0.002

[1] Only sufficient sample for a preliminary qualitative analysis; values may be in error up to 100%.

DESCRIPTION OF DEPOSITS

MACASSA GOLD MINES LIMITED

In 1963, Macassa Gold Mines Limited held a group of 25 surveyed claims in lot 31, concession VIII, lots 27 to 30, concessions VI and VII, and lots 26 to 28 and lot 30, concession V, Limerick Township (No. 3 on Map 2167). The north end of the claim group is traversed by the Coe Hill branch of the Canadian National railway, and Highway 62 is 525 feet east of the northeast corner of the claim group.

In the summer of 1961, nickel and copper mineralization was discovered near the north end of the property in a reverse L-shaped electromagnetic anomaly near the common corners of lots 28 and 29, concessions VI and VII. Between September, 1961 and April, 1962, an access road was constructed between Highway 62 and the property, and the anomaly was explored by 23 diamond-drill holes totalling 13,640 feet.

The mineralization is confined to metapyroxenite found within the northeast corner of the Thanet Complex where an apophysis of uralitized diorite and gabbro extends northward into the Turriff metavolcanics for 750 feet and then northeastward for at least 300 feet along the contact of the Turriff metavolcanics and the Vansickle formation. Contacts of this part of the complex dip 60 to 85 degrees west to northwest parallel to the dip of the country rocks which, immediately adjacent to the intrusion, contain numerous pyrite- and pyrrhotite-bearing rusty schist zones and a few dikes and sill-like bodies of tonalite, uralitized diorite, and metapyroxenite ranging in width from ½ foot to 40 feet. The general geological relationships are shown in Figure 7 which was prepared by the author from data collected by logging the drill core and from diamond-drill hole plans and sections supplied by Macassa.

Although the uralitized diorite and gabbro are exposed in many places, the mineralized zone is not exposed, and only two outcrops of metapyroxenite were found, one in lot 28, concession VI, on the south side of the access road, and the other in lot 28, concession VII, a few feet north of the railway track. Surface projections up dip of the main metapyroxenite unit and its mineralized zone as shown in Figure 7 were generalized from the subsurface data, and in actual fact irregularly shaped, uralitized gabbro and diorite masses, tonalite dikes, fine-grained diorite dikes, and inclusions of the country rocks are abundant locally within the metapyroxenite. South of the main unit a second metapyroxenite unit, which is also partly mineralized, was intersected by four of the drill holes (Figure 7), but the extent of this unit and its relationship to the main unit are unknown. Other narrow zones of partly mineralized metapyroxenite, which do not appear to be persistent either along the strike or down the dip, are rare north and west of the main metapyroxenite unit.

Less than 10 percent disseminated sulphide minerals are present in the metapyroxenite which consists largely of completely uralitized pyroxene. For the most part, the metapyroxenite is in sharp contact with its wallrocks, but, locally, metapyroxenite grades into uralitized gabbro, and diorite rich in ferromagnesian

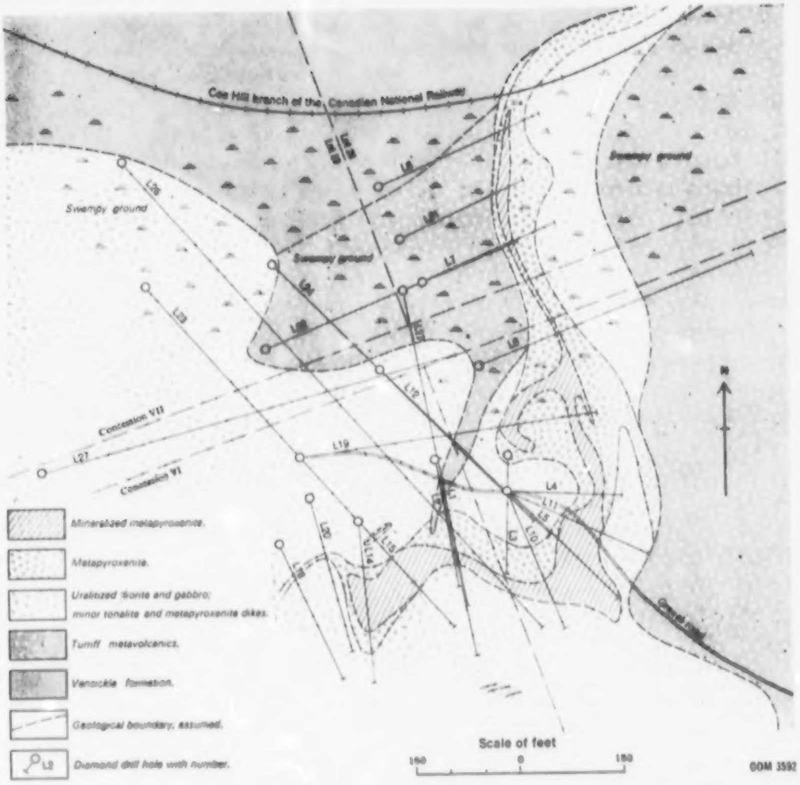
Coe Hill branch of the Canadian National Railway
Swampy ground
Swampy ground
Swampy ground
L25
L23
L27
L19
L4
L12
L11
L5
L10
L7
L6
L9
Concession VII
Concession VI
Gravel road
N
Mineralized metapyroxenite.
Metapyroxenite.
Uralitized diorite and gabbro;
minor tonalite and metapyroxenite dikes.
Turriff metavolcanics.
Venackie formation.
Geological boundary, assumed.
L2
Diamond drill hole with number.
Scale of feet
150
0
150
ODM 3592

Figure 7–Surface plan showing the general geology and mineralized zones, Macassa Gold Mines Limited, Limerick Township.

minerals. Within the main metapyroxenite unit, the mineralized zone, which appears to form about a third of the unit, is distinguished by a sulphide mineral content greater than 10 percent and by a dark-grey gangue composed largely of talc and minor actinolite. The mineralized zone and the metapyroxenite are either in sharp contact, or the mineralized zone grades over a few inches to a few feet into sparsely mineralized actinolite-talc schist and metapyroxenite. The mineralized zone is either in sharp contact with the uralitized diorite and gabbro, the tonalite, and the country rocks, or is separated from these rocks by narrow silicified zones generally less than 1 foot wide.

A vertical section across the main metapyroxenite unit given by drill holes No. L-5, L-12, and L-24 (Figure 8) shows that the unit varies in width not only along the strike, but also down the dip. In general, the mineralized zone, which

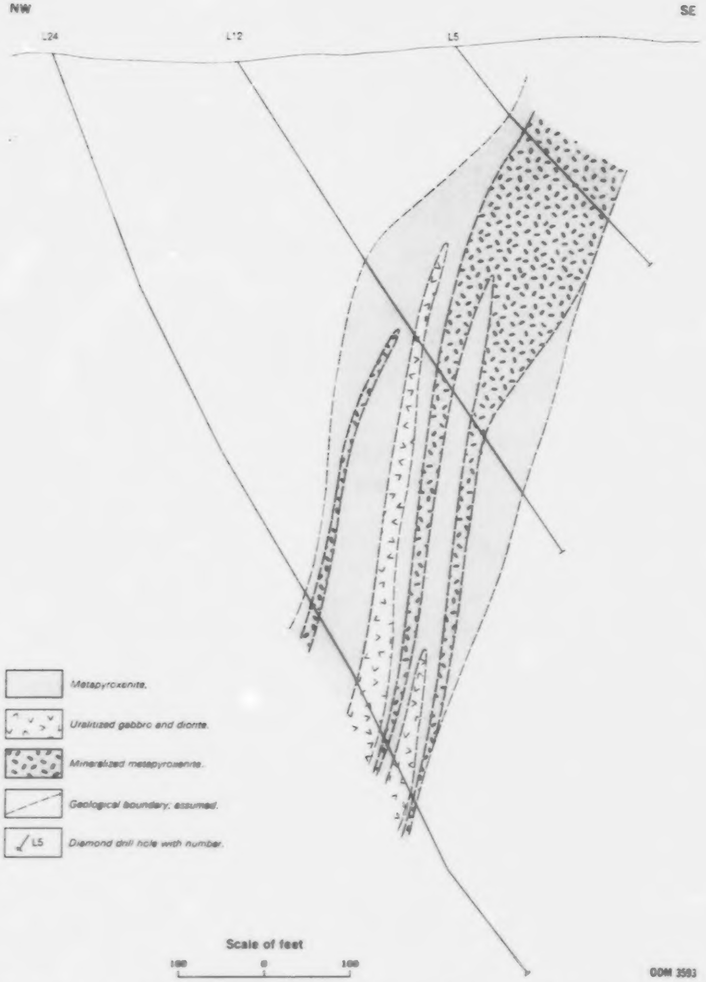
NW
SE
L24
L12
L5
Metapyroxenite.
Uralitized gabbro and diorite.
Mineralized metapyroxenite.
Geological boundary; assumed.
L5
Diamond drill hole with number.
Scale of feet
100
0
100
ODM 3593

Figure 8–Vertical section through the main mineralized zone, Macassa Gold Mines Limited, Limerick Township.

is irregularly distributed within the main metapyroxenite unit, pinches and swells both along the strike and down the dip, and branching of the zone is common, particularly down the dip.

The mineralized zone contains 10 to 70 percent, fine- to medium-grained sulphide minerals which, in order of abundance, consist of pyrrhotite, pentlandite, pyrite, chalcopyrite, and trace amounts of cubanite and sphalerite. Most of the pentlandite is found as finely exsolved flames and lamellae in pyrrhotite, but some fine-grained pentlandite is interstitial to the pyrrhotite. Rarely forming more than 10 percent of the sulphide minerals, pyrite is absent in many of the drill core sections of the mineralized zone. Pyrite is found as separate grains intergrown with pyrrhotite, as inclusions in pyrrhotite and pentlandite, and as narrow rims on pyrrhotite grains. Chalcopyrite, which rarely forms more than 5 percent of the sulphide minerals, commonly replaces pyrrhotite and pentlandite and forms inclusions in pyrite.

Chalcopyrite veinlets are present locally in the mineralized zone, and veins as much as half an inch wide composed of various mixtures of pyrite, chalcopyrite, and pyrrhotite are present in carbonatized and silicified zones in metapyroxenite and uralitized gabbro and diorite found near the mineralized metapyroxenite. These veins and the microtextures of the sulphide minerals suggest that pyrrohtite and pentlandite began to crystallize before pyrite and that much of the chalcopyrite crystallized after the pyrrhotite, pentlandite, and pyrite.

In an article published in the Northern Miner on April 12, 1962, Macassa, on the basis of data collected from the 23 diamond-drill holes, estimated 2,000,000 tons of mineralized metapyroxenite down to the 1,000-foot level grading 1 percent nickel and 0.25 percent copper. According to copper and nickel assays made by Macassa from split drill core, the grade of the copper and nickel mineralization is relatively persistent with depth, but the southern part of the mineralized zone appears to be slightly richer in nickel and copper than the northern part of the zone. Average nickel assays as high as 1.77 percent over 66 feet and as low as 0.52 percent over 21 feet have been obtained. Copper is rarely present in amounts greater than 0.5 percent, and, in general, copper assays are highest where nickel assays are highest. Cobalt is present in the mineralized zone in amounts generally less than 0.1 percent, and traces of gold and silver are common.

Confinement of the copper and nickel mineralization to the metapyroxenite suggests that the deposit may be a magmatic segregation. Nevertheless, the mineralized zone has more intense hydrothermal alteration than the host metapyroxenite, and zones of carbonatization and silicification are common in the mineralized zone and in the adjacent unmineralized rocks. Accessory pyrrhotite in uralitized gabbro and diorite, both in the vicinity of the mineralized metapyroxenite and elsewhere within the intrusion, rarely contains exsolved pentlandite, and, as shown in Table 10, magnetic opaque fractions from the uralitized gabbro and diorite, and the tonalite are relatively high in nickel and cobalt. Further diamond-drilling in zones of metapyroxenite, both in the vicinity of the Macassa deposit and elsewhere in the Thanet Complex, could disclose additional copper and nickel mineralization.

TRIANA EXPLORATION LIMITED[1]

In 1961, Triana Exploration Limited held four unsurveyed claims in the north halves of lots 2 and 3, concession III, and in the south halves of lots 2 and 3, concession IV, Tudor Township (No. 27 on Map 2168). Centred about 3,450 feet north-northeast of the Craig mine, the claims are within the ultramafic rocks of the southwestern part of the Lingham Lake Complex.

In 1957, according to data given in O.D.M. File 63-933, Triana examined copper and nickel mineralization in the southern half of the claim group by means of a magnetometer survey which also covered the northern half of the claim group and parts of lot 4, concessions III and IV, by sinking 10 shallow trenches, and by drilling a few holes with a packsack diamond-drill; data concerning the drilling is given in O.D.M. File EO 24502-4. In 1961, the author visited the 10 trenches which are shown on Map 2168 (back pocket).

With the exception of the most southerly trench, which is in gabbro, all the trenches are in metapyroxenite and metaperidotite, and most are within that part of the ultramafic mass richest in metaperidotite. In general, the ultramafic rocks are poorly exposed, and existing outcrops are intensely weathered. Magnetite is commonly an abundant accessory mineral in the metaperidotite, and both the metaperidotite and metapyroxenite contain abundant talc and serpentine. Where mineralized at the 10 trenches, the mafic rocks contain a few discontinuous quartz veins only a few inches wide, irregularly distributed silicified zones, and 5 to 20 percent disseminated, fine- to medium-grained sulphide minerals which in order of abundance consist of pyrrhotite, pentlandite, chalcopyrite, and pyrite. Pentlandite is found as microscopic, exsolution flames and lamellae in the pyrrhotite. Chalcopyrite rarely forms more than 5 percent of the sulphide minerals, and pyrite, which generally forms less than 2 percent of the sulphide minerals appears to be absent in many of the trenches. Additional occurrences of disseminated pyrrhotite, chalcopyrite, and pyrite within the ultramafic mass are shown by the symbol S on Map 2168 (back pocket).

Six grab samples collected by the author from the six most southerly trenches in the north halves of lots 2 and 3, concession III, gave upon assay a trace to 0.16 percent copper and 0.02 to 0.48 percent nickel; one sample gave 0.01 ounce gold per ton, three gave a trace of gold, and two contained no gold. A grab sample collected by the author from a small mass of metaperidotite containing 10 percent disseminated pyrrhotite, minor pyrite, and rare chalcopyrite, near the eastern boundary of lot 5, concession III, gave upon assay 0.09 percent nickel and traces of copper and gold. According to drilling and assay data submitted by Triana on four holes, each less than 100 feet (O.D.M. File EO 24502-4), several zones containing disseminated sulphide minerals were intersected. The highest nickel concentrations obtained were 0.95 percent over 4 inches, 0.83 percent over 6.5 feet, and 0.70 percent over 17 feet. Copper concentrations do not exceed 0.45 percent in any of the sections assayed, and the copper concentration lies generally between 0.10 and 0.30 percent.

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[1] During the spring of 1967, Louada Exploration and Development Co. Ltd. drilled three holes ranging in depth from 106 to 124 feet in the north halves of lots 2 and 3, concession III, Tudor Township (O.D.M. File EO 33104-5), about 400 feet north of the most northerly trench put down by Triana in these lots. Most of the core is altered ultramafic rocks containing a few narrow zones of 1 to 10 percent disseminated sulphide minerals. Assay results from the mineralized zones indicate nickel concentrations ranging from a trace to 0.90 percent and copper concentrations less than 0.35 percent.

Iron and Titanium

Concentrations of iron-titanium oxide minerals are relatively common within the map-area and are found in three major types of deposits which, in order of their relative abundance are: 1) low titanium, contact metasomatic deposits; 2) siliceous iron formation associated with metavolcanics; and 3) high-titanium, magmatic segregation deposits. Titanium is concentrated mainly with iron in the magmatic segregation deposits which contain abundant ilmenite. Nevertheless, in a few places within almandine amphibolite facies metavolcanics such as in lot 19, concession XII, Limerick Township, crystals of rutile as much as 1 inch long are found locally in quartz veins.

The contact metasomatic deposits, which are found exclusively in metasomatized carbonate metasediments within the innermost parts of contact metamorphic aureoles, contain less than 1 percent titanium and are associated mainly with sodic granitic and syenitic intrusive rocks; one deposit, the St. Charles mine, is associated with the Tudor Gabbro. Siliceous iron formation is rare within the Tudor metavolcanics but is relatively common within the Turriff metavolcanics. The magmatic segregation deposits, which contain more than 1 percent titanium, are found within the Tudor and Umfraville Gabbros which are the only intrusions in the map-area that underwent differentiation in place. Compared with mafic phases of the composite mafic intrusions in the map-area, the mafic phases of the Umfraville and Tudor Gabbros contain more magnetite, and the gabbros of these two intrusions have higher ferric to ferrous iron ratios than analysed gabbros from the composite mafic intrusions (Table 7).

Only the contact metasomatic and magmatic segregation deposits have been explored. Because most of this work was done during the late 1800s and early 1900s, showings are now in poor condition for examination, and reliable data concerning geological relationships, dimensions, and grade of showings are scarce. From the data available, all the iron-titanium oxide deposits found within the map-area appear to be relatively small in comparison with similar deposits found elsewhere in the Bancroft–Madoc area (Lumbers 1964; Rose 1958), but at least some of the deposits in the map-area do not appear to have been explored by modern techniques. Indeed, Lindeman (1913, p. 5), who examined many of the showings both within and without the map-area either during, or shortly after they were worked, states:

> It is very difficult to estimate with even an approximate correctness the quantity of ore available in this district, because of the lack of sufficient development and of the exceedingly irregular character of the ore bodies.

DESCRIPTION OF DEPOSITS

Contact Metasomatic Deposits

ST. CHARLES MINE

The St. Charles mine (No. 21 on Map 2168), which was originally owned by the Anglo-American Iron Company and is now owned by The International Nickel Company of Canada Limited, is in lot 19, concession XI, Tudor Township, about 700 feet west of Highway 62. According to DeKalb (1901, p. 128), magnetite was mined from four open pits, and in 1901, 4,500 tons of ore were hauled along a wagon road leading eastward from the property to McDonalds siding on the railway. Only 3,000 tons of the ore were shipped, and in 1961, what may be the remaining 1,500 tons of ore was present in a small stockpile on the east side of the railway.

Details of the development work at the mine are given by Carter (1902, p. 261) who states as follows:

> The original 300-foot open cut is abandoned for the present, but at 25 feet beyond its west end another pit 8 by 10 feet in surface area and 10 feet deep is being sunk in the narrowing continuation of the vein in the big cut and entirely in the magnetic ore. At 25 feet west of the centre of this main pit another parallel body is opening up, the size of which at the time of my visit, 7th December 1901, was 40 feet long by 10 feet wide and 10 feet deep between walls of diorite, both ends and the floor showing clean, compact ore. Near the side limits, however, considerable granular calcite is intermixed and overcaps a portion of the magnetite body. West of this about 50 feet a fourth pit had been stoped out by the former operators 15 feet deep and 25 by 25 feet in plan, but mining on it had not been resumed. At a point 100 feet north of the open cuts an outcropping of ore on another one of the series of parallel lenses was stripped preparatory to development in the near future. The system of raising the ore from the pits is by derrick and horse whim, dumping on to platforms to be drawn over a mile road to the railroad.

The general geological relationships of the deposit are shown in Figure 9 which was modified by the author after Lindeman and Bolton (1917, Map 187A) and Rose (1958, Figure 19). Magnetite mineralization is confined to a thin, lens-like, carbonate metasedimentary member in mafic metavolcanics of the Tudor metavolcanics which form a small re-entrant in the northeastern tip of the Tudor Gabbro. Separating trondhjemite on the west from diorite on the east, the mafic metavolcanics of the re-entrant contain numerous fine-grained and medium-grained diorite dikes, irregularly shaped masses of medium-grained diorite, and, locally, a few trondhjemite dikes. The marginal phase of the diorite is commonly massive, fine-grained, and dark-green, and is similar in appearance to the hornfelsed mafic metavolcanics.

Striking about N80°E and dipping 45 to 60 degrees north, the carbonate metasedimentary member was intruded by fine-grained diorite dikes generally less than 3 feet wide and, at its eastern end, by the diorite. Locally, the carbonate metasediments, which consist mainly of medium- and coarse-grained marbles, were metasomatized and converted to mafic tactite consisting largely of various mixtures of andraditic garnet, clinopyroxene (a member of the diopside-hedenbergite series), pistacite, hornblende, calcite, and less than 10 percent magnetite; garnet is concentrated locally near the margins of the tactite. Three main zones of magnetite-rich tactite are present (Figure 9) in which more than 10 percent of the rock consists of fine- to medium-grained magnetite as disseminated

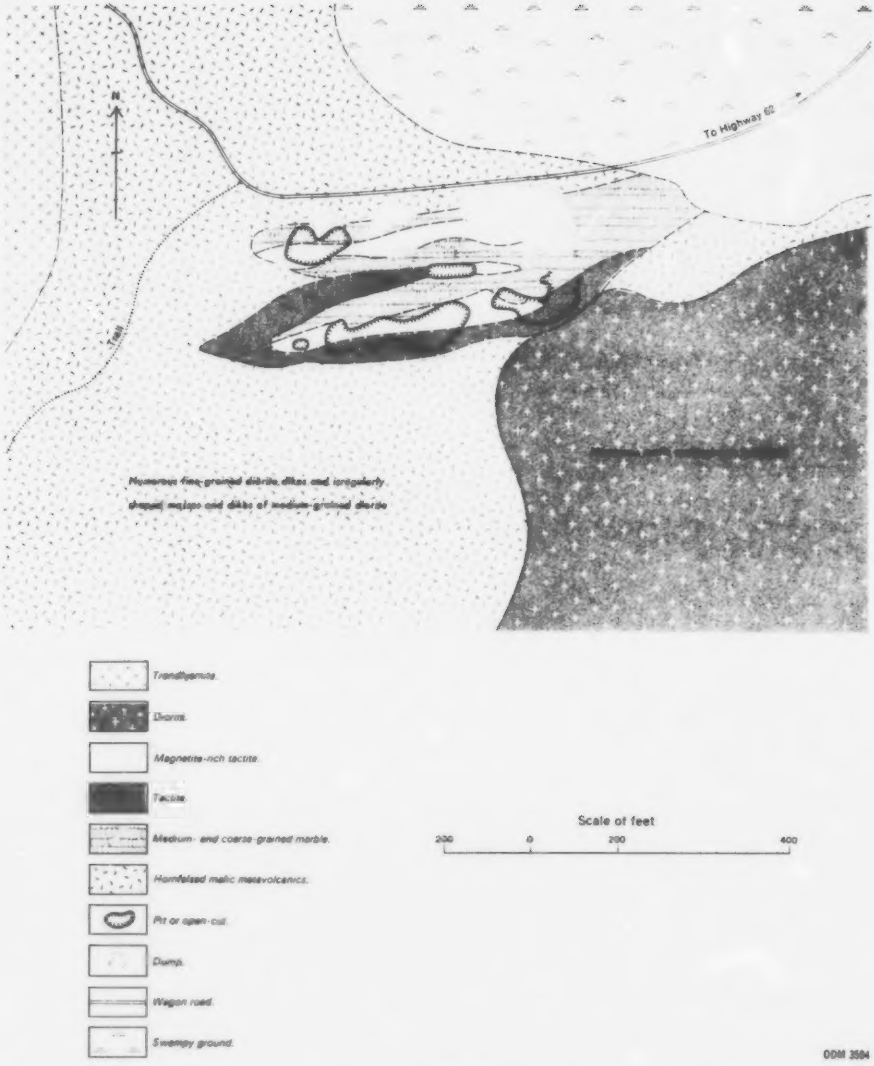
N
To Highway 62
Trail
Numerous fine-grained diorite dikes and irregularly shaped masses and dikes of medium-grained diorite
Trondhjemite.
Diorite.
Magnetite-rich tactite.
Tactite.
Medium- and coarse-grained marble.
Hornfelsed mafic metavolcanics.
Pit or open-cut.
Dump.
Wagon road.
Swampy ground.
Scale of feet
200
0
200
400
ODM 3594

Figure 9–Sketch map of the geology and workings, St. Charles mine, Tudor Township.

grains, as massive stringers, and as irregularly shaped massive bodies; the largest body of massive magnetite appears to be present in the most southerly of the three zones. Garnet and coarse-grained calcite as veins and irregularly shaped masses are the most abundant gangue minerals in the magnetite-rich zones, and pyrite, pyrrhotite, and chalcopyrite, which locally form veinlets, are erratically disseminated throughout the three zones. According to data presented by Rose (1958, p. 80) the magnetite contains less than 1 percent titanium.

DeKalb (1901, p. 128) states that the iron content of the 3,000 tons of ore shipped from the mine ranged from 57 to 64 percent, and that the sulphur content ranged from 0.5 to 1 percent. An average sample taken by Lindeman (1913, p. 13) across the magnetite-rich tactite in the open-cut nearest the diorite (Figure 9), gave 42.00 percent iron, 0.832 percent sulphur, and 0.080 percent phosphorus. A grab sample collected by Thomson (1943, p. 48) consisting of about 50 small pieces of the best mineralized material from the dumps gave 50.69 percent iron, 6.83 percent silica, 0.45 percent titania, 0.64 percent sulphur, and 0.09 percent phosphorus.

GLANMIRE LAKE

On the northwest shore of Glanmire Lake in lot 26, concession XIV, Tudor Township (No. 13 on Map 2168) magnetite-rich, mafic tactite is exposed over an area of about 40 square feet. The tactite, which is in marble separating the southern and central intrusive centres of the Glanmire Complex, contains about 25 percent disseminated fine-grained magnetite in a gangue composed largely of clinopyroxene and pistacite. No exposures of the tactite were found inland from the lake shore.

LEE MINE

An open-cut about 60 feet long, as much as 10 feet wide, with an 8-foot face, and close to the boundary of lot 21, concessions XVII and XVIII, Tudor Township, is referred to by Thomson (1943, p. 48-49) as the Lee mine (No. 22 on Map 2168). A small dump about 60 feet southwest of the cut is on the northeast side of the wagon road that extends from Highway 62 across Beaver Creek to the west end of Steenburg Lake.

The cut is within the southwestern margin of the Beaver Creek Complex near the contact between a coarse-grained marble inclusion and amphibole-rich albite syenite and fine-grained albite syenite. In the face of the cut, a 6-foot wide zone of massive, fine-grained magnetite dipping 75 degrees southeast is exposed between a footwall of coarse-grained marble and a hangingwall of fine-grained albite syenite. Much pyrite, minor pyrrhotite, and rare chalcopyrite are disseminated in the massive magnetite which contains a few irregularly shaped masses and veinlets of calcite intergrown with minor amounts of amphibole. A grab sample of the magnetite rock taken from the dump by Thomson gave upon analysis 47.87 percent iron, 6.64 percent silica, 0.25 percent titania, 0.08 percent sulphur, 0.08 percent phosphorus, and no vanadium.

BAKER MINE

The Baker mine (No. 1 on Map 2168), is in lot 18, concession XVIII, Tudor Township, within a steeply eastward dipping screen of carbonate metasediments in the west-central marginal portion of the Beaver Creek Complex. Workings

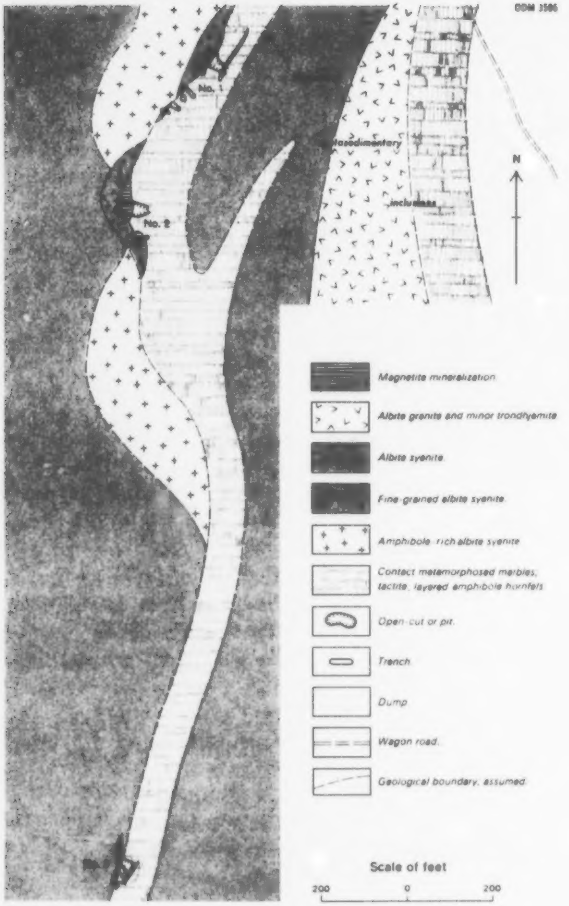
ODM 3586
No. 1
No. 2
Metasedimentary
inclusions
N
Magnetite mineralization
Albite granite and minor trondhjemite
Albite syenite
Fine-grained albite syenite
Amphibole-rich albite syenite
Contact metamorphosed marbles, tactite, layered amphibole hornfels
Open-cut or pit
Trench
Dump
Wagon road
Geological boundary, assumed
Scale of feet
200
0
200

Figure 10–Sketch map of the geology and workings, Baker mine, Tudor Township.

consist of two open-cuts and five trenches about 925 feet east of the gravel pit in lot 17, concession XVIII, and two pits about 1,600 feet south of the most southerly of the two cuts (No. 2, Figure 10). In Figure 10, showing the geology in the vicinity of the workings, the author has taken the position and dimensions of the workings from Lindeman and Bolton (1917, Map 188A) and a few of the magnetite-bearing zones from Rose (1958, Figure 3). Lindeman and Bolton's numbering of the open-cuts and pits has been retained by the author.

Lindeman and Bolton (1917, p. 121) describe the workings as follows:

> The workings consist of three open-cuts and a number of test-pits on the eastern slope of a ridge running north and south. The ore is a fine-grained magnetite, intermixed with a large amount of gangue matter, chiefly pyroxene and chlorite. It occurs along the contact of

> crystalline limestone and diorite. Iron pyrites is of common occurrence in the diorite as well as throughout the ore. Judging from the magnetometric survey the ore occurs in small detached bodies or pockets. The largest area of strong magnetic attraction is found around open-cut No. 1. The development work done here has, however, so far failed to reveal any ore of economic importance. The ore-body opened up by open-cut No. 2 has a width of about 25 feet, but the magnetometric survey indicates that its extent is very small. Working No. 3 shows another small pocket of magnetite along the contact of limestone and diorite.

Lindeman (1913, p. 5) notes that the Baker deposit has the highest sulphur content of all the magnetite deposits he examined in the region. Magnetite mineralization seen by the author in cut No. 2 is accompanied by as much as 10 percent disseminated sulphide minerals consisting of pyrite, minor chalcopyrite, and rare pyrrhotite. Most of the gangue in the magnetite-bearing zones is calcite, amphibole, and chlorite; no pyroxene was found by the author in the workings.

An average sample taken across the mineralized zone in cut No. 2 reported by Lindeman and Bolton (1917, p. 121) gave upon analysis 38.70 percent iron, 3.35 percent sulphur, and 0.20 percent phosphorus. A grab sample collected by Thomson (1943, p. 48) from one of the dumps gave upon analysis 46.61 percent iron, 13.48 percent silica, 2.45 percent sulphur, 0.30 percent phosphorus, and no vanadium. Rose (1958, p. 77) reports less than 1 percent titanium in the mineralized material and less than 0.1 percent titanium in the magnetic concentrate.

EMILY MINE

The Emily mine (No. 18 on Map 2168), which is near the southeast corner of lot 7, concession XIX, Tudor Township, is within a small re-entrant of carbonate metasediments in the southwestern margin of the Wadsworth Trondhjemite. Workings consist of an open-cut about 125 feet long, 15 feet wide, and with a 20-foot face; a dump is just south of the cut.

Carbonate metasediments within the cut and south of the cut near the margin of the intrusion underwent silica, alumina, and iron metasomatism and were converted to mafic tactite consisting of various mixtures of clinopyroxene (an iron-rich member of the diopside-hedenbergite series), pistacite, andraditic garnet, calcite, plagioclase, and a minor amount of disseminated magnetite. Most of the rocks exposed in the cut consist of mafic tactite with local, irregularly shaped, masses and stringers of fine- to coarse-grained magnetite; part of the east wall of the cut is contaminated trondhjemite. Numerous, vuggy, irregularly shaped, coarse-grained calcite masses, which contain clinopyroxene, pistacite, garnet crystals as much as half an inch across, specularite and magnetite generally less than half an inch across, and crystals and massive aggregates of pyrite, are common in the tactite exposed in the cut. Quartz veins are common near the north end of the cut and contain variable amounts of calcite, pistacite, tremolite, tourmaline, pyrite, magnetite, and specularite. Broken pieces of fine- to medium-grained, massive magnetite on the dump commonly contain disseminated pyrite, pyrrhotite, and, rarely, chalcopyrite.

Lindeman and Bolton (1917, p. 121-122) describe the deposit as follows:

> Chapman, in the transactions of the Royal Society of Canada, 1885, section III, p. 12, describes this as a magnetic ore deposit of considerable extent. He says: "The exposed ore rises in a series of ledges from the level of the ground to a height of from 150 to 180 feet, and extends over a space of at least 1,000 feet in length by 100 feet in breadth." This could not be verified by Lindeman. On lot 7 a somewhat abrupt ridge, chiefly made up of a coarse-grained granite, was found. A large open-cut had been made into the hillside, showing in places some small patches of magnetite heavily intermixed with gangue matter. The magnetic attraction around the open-cut is also very irregular.

During January and February, 1960, the Emily deposit was re-examined by a dip needle survey and diamond-drilling carried out for Edward Barton of Peterborough by B. C. Robson (O.D.M. File EO 27862). This work showed the existence of a northeasterly-trending magnetic anomaly 400 feet long and with an average width of about 75 feet which extends about 225 feet beyond the face of the open-cut. Seven drill holes ranging in length from 46 to 120 feet were put down in the anomaly northeast of the open-cut and intersected a complex assemblage of contaminated trondhjemite, mafic tactite with several zones of disseminated magnetite, a few quartz and carbonate veins, and rare silicified material. According to the drill logs, the mafic tactite is particularly rich in black to dark-brown garnet, and associated magnetite mineralization is mainly within 75 feet of the surface. Only a small tonnage of low grade magnetite-bearing tactite appears to be present; the best grade found in the drilling was 46.54 percent acid soluble iron over about 4 feet.

According to Rose (1958, p. 78) magnetite-rich material from the Emily mine contains less than 1 percent titanium, and a concentrate of this material contains less than 0.01 percent titanium.

LOT 3, CONCESSION XIX, TUDOR TOWNSHIP

On the northwestern shore of Wadsworth Lake near the east boundary of lot 3, concession XIX, Tudor Township (No. 16 on Map 2168), tactite at the southwestern margin of the Wadsworth Trondhjemite contains a few streaks and lens-like masses of magnetite, generally less than 3 inches wide, over a zone about 6 feet wide. Coarse-grained calcite veinlets containing crystals of pistacite, pyrite, and andraditic garnet are common within the magnetite-bearing zone.

Iron Formation

Iron formation is found in the Tudor and Turriff metavolcanics, and the various units are shown on Maps 2167 and 2168 (back pocket). In Tudor Township, iron formation, which is intercalated with mafic metavolcanics in lot 13, concession X, Tudor Township, consists of discontinuous, parallel, magnetite layers ranging in thickness from less than 1 millimetre to 5 millimetres in a fine-grained, granular quartz matrix which contains minor disseminated magnetite, pyrite, and chlorite. In general, the total magnetite content does not exceed 25 percent, but a grab sample collected by the author, which contained abundant magnetite layers, gave upon analysis 50.98 percent iron. Two separate layers were found which could not be traced for more than a few hundred feet; the width of both layers does not exceed 30 feet. A few old pits, which are now largely filled with forest litter, were sunk in the iron formation units.

In the Turriff metavolcanics, narrow iron formation layers which range in thickness from less than 1 foot to about 100 feet are intercalated with both mafic and felsic metavolcanics; these layers are most abundant near the Thanet Complex and west of the Jocko Lake Complex. Except for a larger grain size, numerous, discordant quartz veins, and accessory hornblende and epidote, the iron formation units of the Turriff metavolcanics are mineralogically similar to those of the Tudor metavolcanics. Fine-grained magnetite granules are sparsely disseminated throughout the rock and form thin layers as much as 2 millimetres thick; near the margins of individual units, massive magnetite layers as much as ¾ inch thick are common. Magnetite commonly ranges between 5 and 15 percent and does not exceed 30 percent in any of the layers. In lot 18, concession VI, Limerick Township, a few 6-inch thick, coarse-grained marble layers are interbedded with iron formation which was explored by an old open-cut about 16 feet long, 10 feet wide, and with an 8-foot face. A channel sample collected by the author across an 8-foot thick iron formation unit in lot 11, concession VIII, Limerick Township, about 1,850 feet south of Twomile Lake, gave upon analysis 24.49 percent iron, 0.03 percent sulphur, a trace of titanium, and no phosphorus.

Magmatic Segregation Deposits

ORTON MINE

The Orton mine (No. 23 on Map 2168), which is in lots 56 and 57, west of the Hastings Road, Tudor Township, is within the gabbro unit of the Tudor Gabbro on the northeastern edge of the mild positive aeromagnetic anomaly centred about three-quarters of a mile south of Mann Lake (see Figure 3, Chart A, back pocket). Most of the workings are on the power line about 1,650 feet west of its junction with the Hastings Road. Outcrops containing concentrations of iron-titanium oxide minerals and the position of the workings relative to the power line right of way are shown in Figure 11 which was modified by the author after a sketch map by Robinson (1922, Map 581).

Robinson (1922, p. 76-77) describes the deposit as follows:

> During the years 1912 and 1913, the Tivani Steel Company, of Belleville, Ont., mined a few tons of titaniferous magnetite on lots 56 and 57 west of the Hastings road, in Tudor township, Hastings county, Ont. The property, which is also known as the Orton mine, is four miles across country west of McDonald's siding on the Central Ontario branch of the Canadian National railway, and five or six miles by road from Millbridge village on the same railway.
>
> The ore was shipped to Belleville to be used experimentally for the direct production of steel in the company's electric furnace—experiments that are stated to have been technically, if not commercially, successful.
>
> The development work on the property consists of some surface strippings, three small open-cuts, and a shaft 32 feet deep. The ore was obtained from the open-cuts. The shaft is sunk in rock, but a drill hole ending 10 feet below the bottom of the shaft is said to have penetrated ore. A diamond drill-hole put down on the property about 1885 is said to have ended in ore at a depth of 70 feet.
>
> The magnetite is found in small segregated bodies surrounded by particularly basic phases of the massive gabbro-diabase that constitutes bed-rock in the district. Judging by the outcrops and the results of a magnetometric survey of the property, made in 1915, these segregations of magnetite are confined to an area about 700 feet long and 400 feet wide, on the two lots. The largest individual segregation does not appear to be more than 150 feet long nor more than 40 or 50 feet in maximum width. From this size they grade down to insignificant patches a few square feet in extent. The uncertain and pockety nature of their occurrence is illustrated by the . . . magnetometric map . . . [not accompanying this report].
>
> All the magnetite is more or less mixed with black ferromagnesian minerals, even those portions that appear on casual inspection to be solid ore, and there is no sharp line of definition between the ore and the wall-rock.

At the three open-cuts (Figure 11), ilmenite and ilmenomagnetite consisting of exsolved ilmenite lamellae in a magnetite host, form lens-like bodies and discontinuous layers which range in width from 1 inch to 18 feet and which have gradational contacts with massive uralitized gabbro and metapyroxenite host rocks. Locally, the gabbro is compositionally layered due to variations in the abundance of plagioclase, and the ilmenite and ilmenomagnetite concentrations

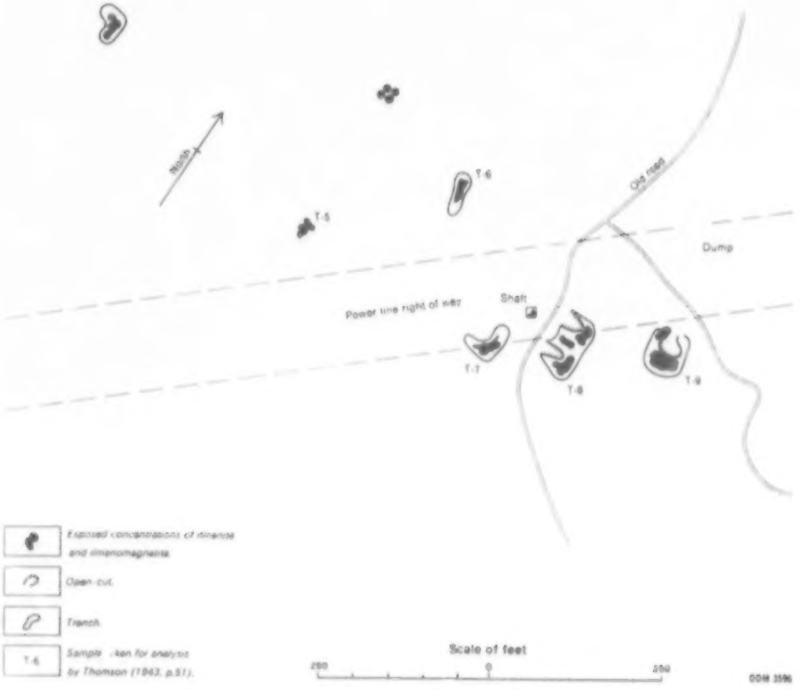
North
T-6
T-5
Old road
Dump
Power line right of way
Shaft
T-7
T-8
T-9
Exposed concentrations of ilmenite and ilmenomagnetite.
Open cut.
Trench.
T-6
Sample taken for analysis by Thomson (1943, p.51).
Scale of feet
200
0
200
ODM 3596

Figure 11–Sketch map of the surface showings, Orton mine, Tudor Township.

generally parallel the layering. Less than 2 percent pyrite is commonly disseminated in the ilmenite and ilmenomagnetite concentrations, and, locally, shear zones are present in which quartz-tourmaline veins containing minor pyrite are concentrated. Gabbro outcrops in the vicinity of the workings contain abundant accessory ilmenomagnetite and ilmenite, and minor accessory pyrite. A small exposure of calc-silicate gneiss is present near the dump on the north side of the power line right of way.

Chemical analyses of mineralized samples taken from the workings by various investigators are summarized in Table 11: analyses Nos. R-1 to R-4 are from Robinson (1922, p. 77); analyses T-5 to T-9 are from Thomson (1943, p. 51); and analysis LB-10 is from Lindeman and Bolton (1917, p. 119). The locations of Thomson's samples are shown in Figure 11.

LOTS 41, 42, 54 AND 55, EAST, AND LOT 55, WEST OF THE HASTINGS ROAD

Local concentrations of iron-titanium oxide minerals within the Tudor Gabbro south of the Orton mine in lots 41, 42, 54, and 55, east of the Hastings Road, and in lot 55, west of the Hastings Road, Tudor Township, are described by Robinson (1922, p. 78) as follows:

Table 11 | CHEMICAL ANALYSES OF MINERALIZED SAMPLES FROM THE ORTON MINE (FROM A VARIETY OF SOURCES MENTIONED IN THE TEXT)

Sample No.	R-1	R-2	R-3	R-4	T-5	T-6	T-7	T-8	T-9	LB-10
Fe*	48.54	54.00	54.72	49.90	53.51	51.48	52.65	55.78	50.62	46.60
SiO_2	10.37	....	....	6.66	2.12	2.64	2.54	3.92	1.97	....
TiO_2	8.17	12.5	13.89	11.83	12.88	9.60	13.20	10.50	10.00	10.00
Al_2O_3	5.01	....	....	....	....	....	....	....	....	....
MgO	4.23	....	....	....	....	....	....	....	....	....
CaO	4.40	....	....	....	....	....	....	....	....	....
Na_2O	0.57	....	....	....	....	....	....	....	....	....
K_2O	0.12	....	....	....	....	....	....	....	....	....
V_2O_5	0.29	0.2	0.34	....	Trace	Trace	Nil	Trace	Trace	....
Cr_2O_3	0.12	....	Trace	....	....	....	....	....	....	....
MnO	0.31	....	....	....	....	....	....	....	....	....
NiO	0.26	0.39	0.11	....	....	....	....	....	....	....
CoO	0.04	....	....	....	....	....	....	....	....	....
$P(P_2O_5)$	0.09	0.041	0.081	0.026	Nil	Nil	0.008	Nil	0.002	0.020
S*	0.04	Trace	0.237	0.256	0.10	0.16	0.25	0.27	0.35	0.06
Moisture	0.47	....	....	....	....	....	....	....	....	....

*Quoted on an oxygen-free basis.

Southeast of the Orton and Ricketts properties, in the same gabbro mass, titaniferous magnetite has also been found on lots 41, 42, 54, and 55 east of the Hastings road and on lot 55 west of it. The country is bush-covered, exposures are few and small, and very little work of any kind has been done. So far as they are visible the occurrences are lean and, individually, small.

A special, picked sample from lot 54 (1) and a general sample from an exposure on lot 42 (2) were analysed in the Mines Branch laboratory by H. A. Leverin, with the following results:

	No. 1	No. 2
Fe	59.85	40.75
TiO_2	13.28	8.50
SiO_2	....	14.00
S	trace	.287
P	.035	.028
V_2O_5	trace	....
Cr_2O_3	trace	....
Ni	trace	....

LOTS 27 AND 28, CONCESSION XV, LIMERICK TOWNSHIP

According to O.D.M. File No. 63A-334, a geological survey was carried out in 1957 by Rio Tinto Canadian Exploration Limited, in a group of four unsurveyed claims in lots 27 and 28, concession XV, Limerick Township, in order to examine the high magnetic intensity of the eastern part of the Umfraville Gabbro. Within the claim group, which is underlain by olivine gabbro, pyroxenite, gabbro, and anorthositic gabbro and diorite, as much as 10 percent disseminated magnetite is reported to be present locally in the gabbro and anorthositic gabbro and diorite.

Other Deposits

LOT 8, CONCESSION XV, TUDOR TOWNSHIP

A magnetite deposit reported by Lindeman (1913, p. 14) to be in lot 8, concession XV, Tudor Township, was not found by the author and is described by Lindeman as follows:

> On the east side of a ridge running approximately north and south on lot 8, concession XV, several strippings have been made showing a grey granite in contact with chlorite and hornblende schist. Associated with the schist are narrow bands of magnetite. The magnetic attraction is rather strong in places, but none of the workings have so far revealed any ore-body of sufficient size to be of economic importance.

RICKETTS IRON MINE

In his original description of the Ricketts iron mine, which actually is just west of the Orton mine in lots 16 and 17, concession XI, Lake Township (Robinson 1922, p. 77-78), Haanel (1909, p. 114) states that this property is in lot 17, concession XI, Tudor Township, about 8 miles from the railway. Although lot 17, concession XI, Tudor Township, is traversed by the railway, this error in the location of the Ricketts property has been perpetuated in reports by Abraham (1951, p. 7), Thomson (1943, p. 47), and Lindeman and Bolton (1917, p. 120), and in the 1923 Report of the Ontario Iron Ore Committee (p. 220). For a description of the property see Laakso (1968, p. 26-27).

Lead and Zinc

With the exception of rare sphalerite in the rusty schists (see "Rusty-Weathering Schists" section), lead and zinc mineralization in the map-area are found as galena and sphalerite in the late calcite and quartz fissure veins (see "Late Calcite and Quartz Fissure Veins"). Within the calcite veins, galena is found in massive pockets and stringers, as disseminated euhedral crystals, and as crystal aggregates; sphalerite, which rarely forms crystal aggregates and is present only in accessory amounts, is commonly confined to quartz-bearing druses in the calcite veins. Many of the calcite veins exhibit comb structure and mineral layering which is accentuated either by accessory sulphide minerals and quartz, or by variable grain size and habit of the calcite. Within the quartz veins, which commonly contain minor calcite and, locally, grade into quartz-bearing calcite veins, galena and sphalerite are either absent, or sparsely disseminated, and coarse-grained crystal aggregates of tourmaline are common; wallrocks are impregnated locally by tourmaline. Both the quartz and calcite veins contain traces of gold and silver, and, locally, some calcite veins contain minor argentiferous tetrahedrite intergrown with galena.

Both along the strike and down the dip, the calcite and quartz veins pinch and swell, and many branch into either parallel veins, or irregularly oriented veins; the form of the veins depends largely on the relative competencies of the wallrocks. The veins are not equally mineralized throughout their length and depth, but data concerning mineralization of the veins at depth is scanty because none have been explored at depths greater than 200 feet. Although calcite and quartz veins are found together in the same country rocks, calcite veins are most abundant in carbonate metasediments, and quartz veins are most abundant in clastic siliceous metasediments and metavolcanics. The largest concentrations of galena found are in drusy calcite veins in carbonate metasediments.

According to reports by Macfarlane (1866, p. 103-105), Vennor (1870, p. 162-164), and Alcock (1930, p. 158-163), as well as data published in Ontario Department of Mines reports, 32 lead prospects are present in the map-area, most of which were worked during the second half of the 1800s. Of the 32 prospects reported, the author could find only five; three other prospects are present which are not recorded in the literature.

DESCRIPTION OF DEPOSITS

Stewart Lead Occurrence

A pit and an old shaft near the southern boundary of Tudor Township, about 1,900 feet east of the Canadian National railway are probably part of the Stewart lead occurrence (No. 26 on Map 2168) which, according to Alcock (1930, p. 160-161) is in lots 1 and 2, concession A, Tudor Township. In 1961, the workings were largely overgrown and in poor condition for examination, but judging from material on a dump near the shaft, the workings are in a calcite fissure vein. Country rocks consist of steeply dipping feldspathic metagreywacke and rusty-weathering schists of the Vansickle formation.

Alcock describes the Stewart deposit as follows:

> The deposit is a vein striking north 45 degrees west magnetic. It has been traced by pits and trenches for 250 feet, and a shaft 20 feet deep has been sunk at one point. The vein varies in width from a few inches to 3 feet. The gangue is calcite. In places it contains small horses of country rock. In the shaft, 10 feet below the surface, the vein has a width of 10 inches and shows solid galena for a width of 5 inches. At the bottom of the shaft the vein is 4 inches wide. In the trenches where the vein widens to 3 feet, there is little galena.

Lot 11, Concession II, Tudor Township

Galena mineralization in calcite veins in lot 11, concession II, Tudor Township (No. 3 on Map 2168), about 400 feet southwest of the southwest corner of Wolf Lake, has been explored by a shaft, two pits, and a 30-foot long trench. The workings were largely filled by debris at the time of the author's visit in July, 1961.

The veins are in vertically dipping metasediments of the Dungannon formation which consist of fine-grained marble with minor, interbedded feldspathic metagreywacke units generally less than 10 feet thick. In the north wall of a pit at the east end of the trench, a narrow calcite vein less than a foot wide, which contains sparsely disseminated, euhedral crystals of galena as much as half an inch across, is exposed. A few unmineralized quartz stringers less than 1 inch wide are exposed in the trench and near the northeast corner of the shaft. Drusy calcite vein material on a dump near the workings contains disseminated quartz crystals, barite, galena, chalcopyrite, pyrite, and, rarely, sphalerite.

Alcock (1930, p. 159), who refers to the property as the Blackburn lead vein, visited the showings in 1925 before all the workings were completed, and gives the following description:

> The deposit is a vein cutting across the sediments. At the time of the writer's visit, in 1925, only one pit, about 7 feet deep, had been opened on it. It showed a vein of calcite up to 6 inches wide and smaller stringers. The vein strikes north 18 degrees west and is vertical. It is well mineralized with galena. Small fragments of country rock are included in the vein and some of them show slickensided surfaces. As exposed at the time of examination the deposit was too small to be of commercial importance.

A grab sample of mineralized calcite vein material collected from the dump by the author gave upon assay 4.04 percent lead, 0.50 percent zinc, and 0.40 ounces silver per ton.

William Ramsey

William Ramsey of Millbridge has stripped and sunk several shallow trenches and pits in galena- and sphalerite-bearing, calcite and quartz fissure veins at his farm in lots 11 and 12, east of the Hastings Road, Tudor Township, between the Hastings Road and Highway 62 (No. 25 on Map 2168).

The fissure veins, which strike about N80°W and dip vertically, commonly pinch and swell along strike, and they cut across a northeast-trending, steeply northwest dipping sequence of interbedded fine-grained marble, feldspathic metagreywacke, calcareous feldspathic metagreywacke, and porphyroblastic actinolite metasediments of the Dungannon formation.

When the author visited the showings in September, 1961, a prominent calcite vein, which ranges in width from ½ foot to 4 feet, had been traced at intervals for about 930 feet by stripping, two trenches, and two shallow pits. A few lens-like calcite stringers elongated parallel to the vein are present in the wallrocks and appear to fill tension fractures. About 160 feet north of the calcite vein, a narrow zone of *en échelon* calcite and quartz veins, which is generally less than 3 feet wide and can be traced for about 200 feet, has been examined by a trench and a shallow pit. About 30 feet north of the west end of this zone, a second narrow zone of *en échelon* calcite and quartz veins, which can be traced for about 330 feet, has been examined by two shallow pits. A prominent topographic lineament, which trends east-northeast to west-northwest, extends across lots 11 and 12 less than 100 feet south of the ½-foot to 4-foot wide calcite vein. A few, discontinuous calcite and quartz veins generally less than 1 foot wide are present south of the lineament, and two of the veins have been examined by shallow pits.

In places, particularly in the central parts, the calcite veins, which are drusy and contain angular inclusions of the country rocks, show comb structure with either a central cavity containing crystals of calcite, quartz, barite, and sulphide minerals, or a central zone of interlocking calcite crystals. The quartz veins, which are drusy locally and rarely contain inclusions of the country rocks, are confined mainly to the metagreywacke and porphyroblastic actinolite metasedimentary units, and tourmaline is commonly present as coarse-grained crystals and crystalline aggregates in the veins and as fine-grained disseminated crystals and massive aggregates in the adjacent country rocks. Most of the mineralization in both vein types is confined to druses. In approximate order of relative abundance, minerals present in the calcite veins are: calcite, barite, galena, quartz, pyrite, sphalerite, and, rarely, pale-green fluorite. Most of these minerals are found as subhedral to euhedral, coarse-grained crystals and crystal aggregates, but some massive pockets of galena are present locally. In their relative order of abundance, minerals present in the quartz veins are: quartz, calcite, tourmaline, pyrite, chalcopyrite, and, rarely, galena and sphalerite.

Three grab samples collected by the author from mineralized calcite veins exposed in the workings gave upon assay 1.46 to 9.18 percent lead and 0 to 0.42

percent zinc. A grab sample collected by the author from a mineralized quartz vein and two of the three grab samples from the calcite veins gave upon assay traces of gold and silver.

Lots 11 and 12, West of the Hastings Road

In lots 11 and 12, west of the Hastings Road, Tudor Township (No. 19 on Map 2168), calcite and quartz fissure veins which trend west-northwest and which have similar characteristics to the veins exposed in the adjacent Ramsey occurrence, have been explored by trenches and pits. The quartz veins, which contain tourmaline, minor calcite, and sparsely disseminated pyrite are confined to a 100-foot thick unit of interbedded feldspathic metagreywacke and porphyroblastic actinolite metasediments which trends northeast, diagonally across lot 11. Near the northwest boundary of the west half of lot 12, a drusy calcite vein which is less than 2 feet wide and contains barite and disseminated, coarse-grained galena crystals, is exposed in a shallow pit put down at the contact between fine-grained marble and a thin calcareous feldspathic metagreywacke unit.

In August, 1960, two short diamond-drill holes were put down in these lots: 1) a 62-foot hole near the northwestern corner of lot 11, 150 feet west of the Hastings Road, and 2) a 57-foot hole near the south-central boundary of lot 12 (O.D.M. File EO 28283-4). Except for a few narrow quartz veins containing minor disseminated pyrite and traces of chalcopyrite, the drilling did not reveal any mineralization.

Lot 33, Concession III, Tudor Township

An old pit, which was largely filled by debris in 1961, is on the south side of the road near the southwest corner of lot 33, concession III, Tudor Township (No. 4 on Map 2168). Broken pieces of drusy calcite vein material containing rare barite and galena crystals were found by the author near the pit. The pit is about 300 feet northeast of a prominent lineament that trends northwest to the Katherine lead mine in Lake Township (Laakso 1968).

Lot 20, West of the Hastings Road

In a field on the northeast side of the road marking the southwestern boundary of lot 20, west of the Hastings Road, an old pit was put down to explore galena mineralization in a calcite fissure vein in fine-grained marble (No. 20 on Map 2168). In 1961, the vein was poorly exposed in the pit, but drusy calcite vein material on a dump near the pit contains coarse-grained crystals of barite, galena, and, rarely, pyrite. Macfarlane (1866, p. 105) mentions the discovery of galena in the southwestern halves of lots 19 and 20, west of the Hastings Road, but no description of the mineralization is given.

Lot 10, Concession V, Tudor Township

An old pit in fine-grained marble in lot 10, concession V, Tudor Township (No. 5 on Map 2168), appears to have been opened to explore calcite and quartz fissure veins. In 1961, the pit was in poor condition for examination, but broken pieces of calcite and quartz vein material were present near the pit. A few barite crystals were found in the calcite vein material.

Lot 29, Concession XIV, Tudor Township

An old shaft, which in 1961 was largely filled with logs and debris, is in a clump of trees in a field near the southwest corner of lot 29, concession XIV, Tudor Township (No. 14 on Map 2168). No bedrock is exposed in the immediate vicinity of the shaft, but near the shaft an old dump, which is largely overgrown by moss and brush, contains drusy, white to pink calcite vein material, some of which has angular fragments of fine-grained marble and metagreywacke. Clusters of barite crystals and a few fine- to medium-grained galena and pyrite crystals were found in the vein material.

Vennor (1870, p. 162-163) describes the deposit as follows:

> On the twenty-eighth and twenty-ninth lots of the fourteenth range of Tudor there is a vein of red and white heavy-spar, holding galena, and cutting the gray calc-schists. Its bearing is N. 5° E.,* and it stands in a vertical attitude, while the enclosing rock, also vertical, strikes almost due north and south. It was discovered some eight years ago, and was first opened in 1859. In 1867 the mine was leased by Messrs. Lombard & Co., of Boston, who were working it at the time of my exploration in Tudor, and I had an opportunity of examining the shaft when free from water. The walls were regular and well defined, the width between them being in some parts from eighteen inches to two feet, and the ore appeared in scattered and irregular bunches in the gangue. When first opened this vein yielded some large masses of ore, but, as in a previously mentioned instance, they greatly diminished, descending, and at the bottom of the shaft, which was twenty-five feet deep, there was scarcely any ore. In 1868, at the depth of forty-two feet, the mine was abandoned. It may be remarked that many of these veins in Tudor, yielding considerable bunches of ore near the surface, shew little more than traces of galena at the depth of a few feet. Of twenty-five localities in Tudor in which galena was discovered and partially worked, but one, the Murphy mine [see p. 94], continued to be worked in 1868. [Vennor's footnote: *The bearings in these descriptions are magnetic, the variation at Madoc being 5° West.]

Bouzan Mines Limited

In 1962, the property of Bouzan Mines Limited consisted of lot 2, concession II, Limerick Township (No. 1 on Map 2167). During 1948 and 1949, Bouzan examined galena mineralization in a calcite fissure vein by surface trenching and 19 diamond-drill holes totalling 3,247 feet (Thomson *et al.* 1952, p. 15). Before Bouzan acquired the property, W. A. McMurray did 375 feet of trenching in the vein (Thomson 1943, p. 55), and Alcock (1930, p. 158-159), who refers to the property as the Chrysler lead property, mentions various open-cuts and pits in the vein. Other workings in the vein, for which no recorded data could be found, consist of a few trenches and an old shaft in lot 1, concession II, Limerick Township. In 1962, the vein was well exposed within the Bouzan property in four trenches totalling 925 feet in length, but in lot 1, the old shaft, which is about 330 feet north of the north-central shore of Little Wadsworth Lake, was partly covered by logs and forest litter, and filled by water to within 15 feet of the surface. Near the shaft an old dump, which is largely overgrown by moss, contains abundant broken pieces of the vein which is poorly exposed in an old trench about 130 feet northwest of the shaft.

Country rocks cut by the vein consist of: 1) marbles, metagreywacke, and calcareous metasandstone and metasiltstone of the Dungannon and Vansickle formations which strike northeast and dip vertically to steeply northwest; and 2) late mafic sills and dikes. The vein, which dips vertically and has an average strike of about N60°W, can be traced at intervals for about 4,000 feet from the old shaft in lot 1, concession II, to the southwest corner of lot 2, concession III, Limerick Township. Along the strike, the vein commonly pinches and swells and ranges in width from ½ foot to 8 feet. Drill hole intersections of the vein at vertical depths as much as 200 feet indicate that the vein also pinches and swells down the dip. Angular inclusions of the country rocks are common in the vein, and from one wall of the vein to the other, bedding in the metasediments is commonly slightly displaced.

The vein contains abundant druses, particularly in the central part where comb structure is present locally. In approximate order of relative abundance, minerals identified in the vein are: calcite, barite, galena, quartz, pyrite, and, rarely, fluorite and sphalerite. Most of the galena is concentrated in the central drusy part of the vein and forms massive pockets and streaks, 2 to 3 inches wide, and coarse-grained crystal aggregates. Some fine- to medium-grained galena crystals and crystal aggregates are sparsely disseminated in other parts of the vein.

Lead assays of drill core intersections of the vein obtained by Bouzan show that the lead content is low; the highest lead content obtained was 0.267 percent over a core length of 3.3 feet. A grab sample of galena-bearing vein material collected by the author from the dump near the old shaft in lot 1, concession II, gave upon assay 5.70 ounces silver per ton and a trace of zinc. Galena from this specimen contained minor amounts of argentiferous tetrahedrite.

Roberts Lead Occurrence

According to Thomson (1943, p. 57) a galena-bearing calcite vein, about 150 feet east of the Canadian National railway in lots 4 and 5, concession B, Tudor Township, has been explored by a shaft, trenches, and pits. When Thomson visited the occurrence, the various workings were partly filled, and in 1961 the author was unable to find the workings. Alcock (1930, p. 160) describes the occurrence as follows:

> LOCATION
>
> The Roberts vein is on lots 4 and 5, block B, Tudor township, county of Hastings. Outcrops of vein material have been found on lots I to VI of block B, in a line running towards the Hollandia vein, and all may belong to the same fault fissure. The chief work has been done near the boundary between lots 4 and 5 near the Canadian National railway about 2-miles northwest of Bannockburn.
>
> GEOLOGY
>
> The rocks of the region are sedimentary gneisses of the Grenville series well exposed in railway cuts near the main workings. The rocks are well banded, strike northeast, and dip about 48 degrees northwest. In places they are crumpled. They are dark coloured, but a lighter quartzitic variety is seen at the shaft.
>
> DEPOSIT
>
> The deposit is a calcite vein carrying galena. In the shaft, which during the winter and spring of 1925 was sunk to a depth of 20 feet, the vein shows a width of 10 inches. There are, in addition, stringers of calcite through the country rock. In the neighbourhood of the shaft the vein has been traced by pits and trenches in a northwest direction for about 200 feet, but away from the shaft it is narrower. The vein is well mineralized with galena and

associated pyrite. The vein as exposed at present is too small to be of economic importance, but considering the excellent lead values it carries and the fact that it is on the same line of strike as the larger Hollandia vein, it is possible that along this zone larger deposits may be present.

Reelman Occurrence

In 1924, George Reelman operated a lead deposit in southern Tudor Township about 1½ miles north of Bannockburn. The only available reference to this deposit (O.D.M. 1925, p. 165) states that a shaft, 7 feet by 11 feet, and 23 feet deep, was put down in lot 9, "block 8", Tudor Township, and that about 5 tons of lead ore were shipped. Because there is no "block 8" in Tudor Township within 1½ miles of Bannockburn, the shaft is probably either in lot 9, concession A, or in lot 9, concession B. A search of both of these lots was made by the author but the shaft was not found.

Lot 23, Concession B, Tudor Township

A galena-bearing calcite vein in lot 23, concession B, Tudor Township, which was not found by the author, is described by Macfarlane (1866, p. 104) as follows:

> On lot twenty-three of block B in Tudor, a two-inch vein is found, which is very well filled with galena. It strikes N.85° W., crossing strata which run N.20° E. and dip 89° westward. A smaller vein, from one half of an inch to one inch wide, runs parallel with the strata, and intersects the other vein.

Lot 28, Concession B, Tudor Township

A lead occurrence reported by Macfarlane (1866, p. 104) and Vennor (1870, p. 163) to be in lot 28, concession B, Tudor Township, was not found by the author. Vennor describes the prospect as follows:

> One of these, on the twenty-eighth lot of range B in Tudor is a vertical vein running N. 70° W*., the strata of calc-schist dipping 274° > 76°. At the time of Mr. Macfarlane's visit a shaft, which had been sunk on it to the depth of thirty-seven feet, was half full of water, preventing him from doing more than to state the information he had received from others. In 1867, I found that the lode, of which the veinstone is barytes and calc-spar, had yielded on the average three quarters of an inch of galena; but the bottom of the shaft showed no more than half an inch of barytes, without galena. I was informed by Mr. W. Kesterman, of Belleville, then superintending the mine, that there had been extracted from the vein about six tons of galena, four and a-quarter tons of which were sent to New York for sale, after being simply crushed, and found to yield 66 percent of lead. [Vennor's footnote: *The bearings in these descriptions are magnetic, the variation at Madoc being 5° West.]

Lot 30, Concession B, Tudor Township

A lead occurrence, which was not found by the author, in lot 30, concession B, Tudor Township, is described by Alcock (1930, p. 162) as follows:

> On block B, lot 30, is a showing on which some work has been done in recent years. A trench 80 feet long has been opened. It shows a vein up to 8 inches in width striking north 75 degrees west magnetic and dipping 80 degrees northeast. The gangue is chiefly barite with minor amounts of calcite. The ore mineral is galena, but is not abundant.

Lot 15, West of the Hastings Road

According to O.D.M. File EO 28285, galena-bearing calcite veins are exposed by blasting in Jordan Creek near the centre of lot 15, west of the Hastings Road, Tudor Township. In 1960, a 104.5-foot diamond-drill hole was put down 7 feet east of the centre of the blasting. The workings were not examined by the author, and minor, disseminated pyrite and pyrrhotite is the only mineralization reported in the drill log.

Murphy Mine

The author was unable to find a galena-bearing calcite vein reported by Macfarlane (1866, p. 104) and Vennor (1870, p. 162) to be in the vicinity of lots 30, 31, and 32, east of the Hastings Road, Tudor Township. Vennor refers to workings in the vein as the Murphy mine.

Macfarlane describes the vein as follows:

> On lots thirty and thirty-one, on the east side of the Hastings road, a vein occurs, having a direction of N.57° to 60° W., and a dip of 75° to 86° south-eastward. It is about eight inches wide, and contains a thickness of from two to three inches of galena. The side-rock is calc-schist, as usual, striking N.86 [°] E., and dipping 55° northward.

Vennor states:

> On the thirty-first and thirty-second lots of the range east of the Hastings road, in Tudor, a lead-bearing vein runs in a vertical attitude N. 57° W.*, cutting the gray calc-schists with strike N. E. E. In 1867 it had been traced, in the direction given, across both the lots mentioned, with very good surface indications, and was known as the Murphy mine. The Hastings Lead-mining Company subsequently sunk a shaft on it, which, I understand, has been carried down to a depth of 125 feet, but the result being unsatisfactory, the work was abandoned. [Vennor's footnote: *The bearings in these descriptions are magnetic, the variation at Madoc being 5° West.]

Lot 34, Concession IV, Tudor Township

Macfarlane (1866, p. 104) refers to a calcite vein in lot 34, concession IV, Tudor Township which contains "four inches of galena". The vein was not found by the author.

Other Occurrences

Macfarlane (1866, p. 105) lists, but does not describe, several localities in Tudor and Limerick Townships at which galena mineralization in calcite veins is found. Nevertheless, no calcite veins were found by the author at the various localities listed which are as follows:

Tudor Township

Lots 2 and 3, lots 15 to 18, and lots 31 and 32, west of Hastings Road; lots 13 to 16, lots 24 to 29, and lot 33 east of Hastings Road; lots 21 to 28, concession A; lots 6 and 27, concession B; lot 32, concession III, lot 12, concession V; lot 11, concession VI; lot 10, concession VII; and lots 26 to 28, concession XIX.

Limerick Township
Lots 27 to 29, concession II.

Silver

Trace amounts of silver are common in many of the gold- and arsenopyrite-bearing quartz veins and in the late quartz and calcite fissure veins. Of the various gold and arsenopyrite deposits examined by the author in the map-area, the Craig deposit (see section on "Craig Mine") appears to have the greatest concentration of silver; as much as 1.95 ounces silver per ton were present in grab samples collected from this deposit. Nevertheless, the greatest concentrations of silver found in the map-area are in the late, galena-bearing, calcite fissure veins in which the silver appears to be in argentiferous tetrahedrite which, when present, is generally intergrown with the galena. As much as 5.70 ounces silver per ton were present in grab samples collected from these veins (see "Bouzan Mines Ltd." section), but further study of the veins is needed in order to determine the distribution and abundance of silver.

Bismuth

In lot 34, concession III, Tudor Township, Vennor (1870, p. 171) and Willimott (1885, p. 9L) examined bismuth mineralization in tourmaline-bearing quartz veins which were explored by two shafts abandoned in 1868. Native bismuth, bismuthinite, and bismutite were found by Vennor and Willimott in the veins which were looked for, but not found, by the author.

Concerning the deposit Vennor states:

> The occurrence of carbonate of bismuth in the township of Tudor has been alluded to by Dr. Hunt in his Report on the gold region of Hastings, in 1867, (page 6). It was found on lot thirty-four of the third range of Tudor, in a vein cutting the hornblendic rocks of division B, and an overlying magnesian limestone, the dip of which was about forty-five degrees to the north of west. The vein, which is very irregular in size, sometimes attains a breadth of two feet or more, and runs north-west, dipping at a high angle to the south-westward. The veinstone was chiefly vitreous quartz, carrying near the surface small masses of carbonate of bismuth, which, lower down, were replaced by the sulphuret, with traces of metallic bismuth. Fine crystalline specimens of the sulphuret of bismuth, several ounces in weight, were sometimes met with; but this valuable ore was sparsely and irregularly disseminated in the quartzose gangue, which also enclosed irregular layers of impure graphite, and masses of radiated black tourmaline, which were sometimes found to penetrate the bismuth ore. In sinking, the quartz veinstone was in parts replaced by an aggregate of pink crystalline calcspar enclosing small crystals of yellow mica, which were also met with in the adjacent quartz. Iron pyrites in imperfect crystals and small masses was also observed in the calcareous portion of the vein. Dr. Hunt, to whom I am indebted for these notices of the minerals of this curious vein, assayed the bismuth ore for gold and silver, but found neither. After considerable working this vein was abandoned in 1868.

Willimott refers to the deposit as Smith's mine and states as follows:

> SMITH'S MINE
>
> is on Lot 34, Range III, of Tudor. It was worked about twelve years ago by Messrs. Hill and Curshaw, with what result I could not ascertain. Two shafts were sunk to the respective depths of twenty and fifty feet, the veins of quartz striking into the enclosing limestone. At the time of my visit the shafts had partly caved in, and could not be examined. The veins, however, crop out near the shaft and maintain an almost horizontal position from one shaft

to the other. They vary in width from one to twelve feet, consisting of an intermixture of quartz and a talcoid, schistose rock, associated with black tourmaline, in abundance, and fibro-lamellar masses of bismuthinite often penetrated by accicular prisms of tourmaline.

NONMETALLIC MINERALS AND INDUSTRIALLY USEFUL ROCKS

Barite

Barite, as coarse-grained tabular crystals and as rosette-like aggregates of tabular crystals, locally forms as much as 20 percent of some late calcite fissure veins. Most of the barite is concentrated in drusy portions of the veins and is commonly associated with the galena mineralization. Barite is particularly abundant in calcite veins of the Ramsey prospect (see "William Ramsey" section).

Talc and Tremolite

Talc is relatively common in metasomatized carbonate metasediments near the south end of the albite granite intrusion in lot 7, concession IV, Limerick Township, and in metapyroxenite and metaperidotite of the Lingham Lake, Thanet, and Jocko Lake Complexes. Nevertheless, in all of these occurrences the talc mineralization, which is intimately associated with iron-titanium oxide minerals and iron-bearing silicate minerals, is not of sufficient size, purity, and whiteness to be of commercial interest.

Minor concentrations of white tremolite accompanied by small amounts of calcite, dolomite and, rarely, talc are found locally in contact metamorphosed marbles near contacts of intrusive rocks of the Tudor Gabbro, the Beaver Creek Complex, and the Wadsworth Trondhjemite. The largest concentration of white tremolite found is at the southern margin of the Tudor Gabbro, about three-quarters of a mile west of the Hastings Road in the north halves of lots 33 and 34, concession VII, Tudor Township. Here, white tremolite as medium- to coarse-grained fibrous masses and as crystals as long as 2 inches forms narrow, lens-like zones, generally only a few feet wide, in calc-silicate gneiss.

Marble

Within the map-area, regional and contact metamorphism of the carbonate metasediments produced a large variety of marbles and calc-silicate rocks (see Table 3) which are potential sources of building stone and terrazzo chips. With increasing metamorphic grade, non-carbonate mineral impurities in the carbonate metasediments become segregated into discontinuous layers or lens-like bodies, the average grain size of calcite increases, and the degree of preservation of bedding decreases. Greenschist facies carbonate metasediments commonly break readily along thin, closely spaced, silicate mineral-rich interbeds, but because of the increased grain size and decreased degree of preservation of bedding, carbonate metasediments metamorphosed to the almandine amphibolite facies are more massive and compact than in the greenschist facies, and break with difficulty along relic silicate mineral-rich interbeds.

Greenschist facies carbonate metasediments are dark-grey to grey, due to abundant dust-like flakes of graphite; with increasing metamorphic grade, graphite becomes coarser in grain, and almandine amphibolite facies carbonate metasediments are generally light-grey to white. Medium- to coarse-grained white marbles, which locally contain pink and pale-brown streaks due to the alteration of accessory sulphide and iron-titanium oxide minerals, are most common in contact metamorphic aureoles and in the hinge portion of overfolds in eastern Limerick Township. Carbonate metasediments exhibiting other colours are rare, but buff, brownish-green, pale-green, green, and dark-green layered diopside hornfels, tactite, and calc-silicate granofels and gneiss are found in contact metamorphic aureoles of the Tudor Gabbro, the Wadsworth Trondhjemite, the Thanet Complex, and the Umfraville Gabbro.

Several specimens of typical greenschist and almandine amphibolite facies marbles were cut and polished with the following results:

1. Polished surfaces of fine-grained marble and fine-grained phlogopitic and tremolitic marble are dark-grey to black with glistening specks of phlogopite and a few, thin, irregularly distributed, white calcite veinlets.

2. Polished surfaces of fine- to medium-grained marble commonly contain alternating light-grey and dark-grey bands ranging in width from about 1 millimetre to 10 millimetres. Medium- to coarse-grained, white calcite veinlets and lens-like masses discordant and concordant to the banding are common.

3. Polished surfaces of medium-grained marble and calc-silicate gneiss are commonly coarsely banded with light-grey, calcite-rich bands speckled with biotite flakes alternating with dark-grey bands rich in biotite and amphibole and containing a few black circular patches of amphibole porphyroblasts as much as a quarter of an inch across. The dark-grey bands are much more abundant in the gneiss than in the marble.

Within the northeastern part of the Wadsworth Trondhjemite contact metamorphic aureole, some mafic tactites, which contain abundant, coarse-grained, brown garnet porphyroblasts disseminated in a fine-grained, light-green matrix consisting largely of diopside, calcite, and epidote, take an excellent polish and have a striking speckled appearance.

From tests made on various types of marble quarried for terrazzo chips in Madoc Township, Hewitt (1964) concludes that fine-grained marbles are harder, stronger, and more durable than coarse-grained marbles. Thus, according to these tests, the most favourable carbonate metasediments in the map-area for use as terrazzo chips would be the greenschist and albite-epidote hornfels facies marbles, layered diopside hornfels, and tactite. Most of the marbles are rich in calcite and are attacked easily by acids, but calcite is generally not abundant in the layered diopside hornfels and tactite.

Massive Metavolcanics

Middle greenschist facies, massive, fine-grained metavolcanics of the Tudor metavolcanics exposed in the vicinity of Jordan and Glanmire Lakes in lots 16 to 24, concessions XII to XV, Tudor Township, and east of Wolf Lake in lots 7 to 9, concessions I, II, III, Tudor Township, are potential sources of roofing granules and terrazzo aggregate. Most of these areas are underlain by mafic metavolcanics, but felsic metavolcanic flows are abundant locally near Jordan Lake (see Map 2168, back pocket). The mafic metavolcanics are dense, even-grained, dark-green to black rocks, and they have primary microtextures and a subconchoidal fracture. Felsic metavolcanic flows near Jordan Lake weather light-grey and are grey to black on an unweathered surface; they have primary, felty or trachytic microtextures, and a conchoidal fracture. The petrographic characteristics of the metavolcanics, especially the felsic flow rocks, suggest that they are adaptable to colouring.

Sand and Gravel

The main sand and gravel deposits present in the map-area are shown in Figure 2 (Chart A, back pocket). Most of the deposits are thin and are found near the borders of swampy areas and along some of the stream valleys. In deposits north of the water parting in Limerick Township (Figure 2), fine to coarse sand commonly greatly predominates over gravel, but in deposits elsewhere in the map-area, gravel is generally abundant. The thickest and most extensively utilized deposits are in lots 17 to 20, concession IV, and in lots 21 and 22, concession II, Limerick Township.

Marl

Recent deposits of marl, which is still accumulating, are common in shallow lakes and in shallow bays of relatively deep lakes within terranes underlain chiefly by carbonate metasediments. Most of the marl contains abundant impurities such as clay minerals, quartz, and organic matter, and the most extensive deposits appear to be present along the shores and bottoms of the Blue Sea Lakes and Egan Lake in northeastern Limerick Township. Numerous gastropod shells of existing freshwater and land species were collected by Adams and Barlow (1910, p. 388) from marl at the Blue Sea Lakes.

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INDEX

PAGE

- Access 2, 5, 72
- Acknowledgments 2
- Actinolite 12, 51, 73
- Actinolite metasediments 22, 26, 90
  - Photo 25
- Actinolite-talc schist 73
- Aeromagnetic anomalies, notes 3, 56, 84
- Aeromagnetic data 3, 50-51, 56
  - Figure *back pocket*
- Ages of rocks 31, 39, 41, 48
- Agglomerate 14, 16
- Agriculture 3
- Albite-epidote hornfels facies rocks 10, 26, 29, 97
- Albite granite 8, 36, 39, 96
  - Dikes 37, 43
  - Modal analyses, notes 38
  - Stocks 33, 35, 41
- Albite isograd, notes 10
  - Figure *back pocket*
- Albite syenite 37, 80
  - Dikes 38, 43
  - Stocks 33, 35
- Allegheny synclinorium, note 4
- Almandine amphibolite facies rocks 16-18, 25, 28, 97
  - Graphite in 58
  - In Limerick Tp. 12, 33, 38, 77
  - Marble 20, 29
  - Pyrrhotite in 50
  - Quartz vein in 62
  - Regional metamorphism 35
  - Tables 11, 22
- Amphibole-poor mafic metavolcanics 12, 31
- Amphibole-rich albite syenite 37
- Amphibole-rich metavolcanics 12
  - Photo 13
  - Table 11
- Amphibolite 12, 39
  - Contact metamorphic 11, 15
  - Layered, photos 13, 14
- Amygdules 12
- Analyses, chemical, notes 16, 30, 35, 38, 71
  - Diorite, table 40
  - Magnetite, notes 80, 83
  - Metasediments, table 22
  - Metavolcanics, table 15
  - Rusty schists, notes and table 60
  - Samples from Orton mine, table 86
  - Uralitized gabbro, notes 42
- Analyses, microscopic, notes 12, 58
- Analyses, modal, notes 35, 38, 41
  - Diorite, in table 40
  - Metasediments, in table 22
  - Sodic granite, in table 34
- Analyses, spectrographic, notes and table 60, 61
- Analyses, x-ray, notes 58
- Andalusite 10, 16
- Andesine isograd, notes 10
  - Figure *back pocket*
- Andesite and basalt, table 11
- Andesite and dacite, table 11

PAGE

- Andesitic rocks 12, 31
  - In table 11
- Andraditic garnet 29, 78, 82
  - *See also:* Garnet.
- Anglo-American Iron Co.:
  - *See:* International Nickel Co.; St. Charles mine.
- Anomalies, notes 50, 51
  - Aeromagnetic 3, 56, 84
  - Electromagnetic 72
  - Magnetic 83
- Anorthositic diorite 42, 45
- Anorthositic gabbro 42, 45, 86
  - Dikes 46
  - In table 40
- Anticlines 10, 14, 32, 52, 53
  - *See also:* Folds.
- Apatite 12, 16, 30, 48
- Apsley, village of 3
- Argentiferous tetrahedrite 87
- Arkose 49
  - *See also:* Metasediments.
- Arsenic 55, 62-70
- Arsenopyrite 56
  - In greenschist facies rocks 58, 62
  - In potassic rhyolite 69
  - In quartz veins 65, 68, 95
  - In schists 56, 67
  - In silicified mafic metavolcanics 67
- Ashby Tp., note 52
- Assay, notes:
  - Arsenopyrite 68
  - Chalcopyrite 64-65
  - Cobalt 75
  - Copper 64, 65, 75, 76, 77
  - Gold 62, 64, 65, 76, 95
    - Trace 63, 90
  - Lead 89, 92
  - Nickel 75, 76, 77
  - Pyrite 64
  - Silver 64, 89, 92
    - Trace 63, 65, 90
  - Zinc 59, 89, 92
- Auriferous vein, Craig mine 15
- Baker mine 80-82
  - Geology and workings, figure 81
- Bancroft, access route 2
- Bancroft-Madoc area, notes 8, 31, 55, 58, 77
- Bannockburn village, mines near 3, 92, 93
- Barite 55, 88, 92
  - In calcite veins 49, 89, 96
  - In quartz veins 90
- Barrie-Grimsthorpe area:
  - Striae 6
- Barrie Tp., notes 6, 52
- Barton, Edward, of Peterborough 83
- Basalt 12, 16
  - Table 11
  - *See also:* Metavolcanics.
- Basalt and andesite, in table 11
- Base metals 58-96
- Bea Lake, notes 5

PAGE

Bea Lake Syncline ... 53
Bear Shanty Lake ... 45-46
Beaver Creek, notes ... 5, 11, 30, 36, 54
  Lee mine near ... 80
  Metavolcanic-metasedimentary rocks near ... 50
  Tudor metavolcanics near ... 31
Beaver Creek Complex ... 33, 35, 37-38, 80, 96
  In Elzevir-Ashby dome ... 52
  Metaconglomerate in ... 23
  Syncline near ... 53
Bedded rocks ... 7, 22, 28
Belleville, town of:
  Tivani Steel Co. in ... 55, 84
Biotite amphibolite, notes and table ... 11, 14
Bismuth ... 55, 95-96
Bismuthinite ... 95, 96
Bismutite ... 95
Blackburn lead vein, notes ... 88
Blue Sea Lakes ... 5, 7, 98
Boron, notes and table ... 60, 61
Bouzan Gold Mines Ltd. ... 91-92
  Explorations by ... 56
Breccia ... 20, 33, 54
  Flow top ... 12
  Intrusive ... 37, 41, 45, 48
    Photo ... 36
Brecciation ... 53
Brett Lake, notes ... 10, 32, 47, 62
Brinklow Fault ... 54
Brinklow Lake ... 5
Building stone ... 55
  See also: Marble.
Burnt Lake formation ... 8, 30, 31, 32

Calcareous rocks:
  Feldspathic metagreywacke ... 25, 26, 89, 90
  In tables ... 18, 21, 22
  Metasandstone ... 8, 50, 52, 91
  Metasiltstone ... 20, 23, 32, 33
  See also: Metasediments.
Calcite ... 20, 28, 46, 78, 89, 92
  In felsic tactite ... 30
  In greenschist facies rocks ... 58
  In mafic tactite ... 29
  In marble, notes and photo ... 27, 96
  In quartz vein ... 49, 87
  Specularite in ... 82
Calcite veins ... 28, 49-50, 53, 54, 80
  Barite in ... 91, 96
  Galena in ... 55, 56, 88, 94
  In marble ... 26, 90, 97
  Pyrite in ... 83, 89
  Silver in ... 87, 95
  With quartz veins ... 62
Calcitic rocks ... 25, 29, 30
Calc-silicate gneiss ... 28, 29, 85, 96, 97
Campbell Construction Co. Ltd. ... 55
Canadian Copper Co.:
  See: International Nickel Co.
Carbonaceous shales ... 16
Carbonate ... 12, 14, 16, 18, 39
  Metasediments ... 20, 42, 52, 96, 98
    Calcareous metasandstone near ... 25
    Calcite veins in ... 87
    Emily mine in ... 82
    Graphitic rusty schist in ... 59
    In Beaver Creek Complex ... 80

PAGE

    In Dungannon formation ... 8, 30, 31, 32
    In Tudor Gabbro ... 48, 97
    In Wadsworth stocks ... 38
    Magnetite in ... 50, 78
    Metamorphosed ... 26, 28
    Metasomatic deposits in ... 77
    Mineral assemblages in ... 29
    Pyrite in ... 55
    Subdivision of, table ... 19
Carbonatized zones ... 75
Cashel peneplane ... 4, 7, 48
Cashel Tp., notes ... 5
Cenozoic rocks, table ... 8
Chalcopyrite ... 12, 15, 75, 76, 88
  Assay notes ... 64-65
  In mafic tactite ... 30
  In magnetite ... 80, 82
  In McMurray occurrence ... 67
  In metapyroxenite dikes ... 70
  In potassic rhyolite ... 69
  In quartz veins ... 49, 62, 89
  In rusty schists ... 59, 60
Chert, in table ... 18
Chromium, in table ... 61, 71
Chrysler lead property:
  See: Bouzan Gold Mines Ltd.
Clinozoisite-microcline-quartz-diopside-plagioclase hornfels ... 30
Cobalt, notes and tables ... 60, 61, 71, 75
Coe Hill, village of ... 2, 3, 72
Coe Hill Anticline ... 52
Colour phases in rocks:
  Amphibole hornfels ... 26
  Amphibolite ... 12, 14, 15
  Felsic flow rocks ... 16, 98
  Marble ... 26, 28, 29, 97
  Shale ... 49
  Trondhjemite ... 35
Conglomerate ... 18, 23, 49
  See also: Metasediments.
Contact metamorphic aureoles ... 58-63 *passim*, 97
Contact metasomatic deposits ... 70, 77, 78-83
Contact metasomatism ... 50
Copper ... 43, 55, 62, 69
  Assay notes ... 64, 65
  In Lingham Lake Complex ... 41, 56
  In rusty schists ... 60
  In table ... 61, 86
Copper and nickel ... 70-77
Craig deposit:
  See: Craig mine.
Craig Gold Mine and Reduction Co. of Newark, New Jersey:
  See: Craig Gold Mines Ltd.
Craig Gold Mines Ltd. ... 56, 64
Craig mine ... 15, 55, 63-65, 76, 95
Crossfolding ... 53
  See also: Folds.
Crystalline limestone ... 82
Cubanite, trace ... 75
Cummingtonite ... 16
Curshaw, Messrs. Hill and ... 95

Dacite and andesite, table ... 11
  See also: Metavolcanics.
Dacitic volcanic rocks ... 31
Dark Lake ... 5

PAGE

- Decarbonatized metasediments 18
- Deer River 5
- Development work, notes 3, 56
- Diabase-gabbro 84
- Dikes:
  - Felsic 29, 30, 33, 45, 46, 78
    - In Beaver Creek Complex 37
    - In Glanmire Complex 43
    - In Jocko Lake Complex 44
    - In Lingham Lake Complex 68
    - In Umfraville Gabbro 48
    - In Wadsworth stocks 38
  - Mafic 8, 18, 38, 78, 92
    - In Lingham Lake Complex 42
    - In Thanet Complex 44
    - In Tudor Gabbro 43
    - Near Bear Shanty Lake 46
    - Near Brett Lake 47
  - Ultramafic 43
- Diopside-microcline hornfels 30
- Diorite 8, 39, 70, 72, 80, 86
  - Chemical analyses of 40
  - Dikes 42, 43, 44, 46, 78
  - In Baker mine 82
  - In Beaver Creek Complex 35
  - In Glanmire Complex 36
  - In Thanet Complex 51
  - In Umfraville Gabbro 45
  - Uralitized 44, 51, 73
  - *See also:* Metadiorite.
- Dixon Lake 5, 7, 59
- Dixon Lake Syncline 53
- Dolomite 96
- Dolomitic marble 25, 29, 30
- Dolostone, in table 18
- Drainage 5
- Drumlinoid ridges 7
- Drumlins 6, 7
- Dungannon formation rocks .. 8, 30, 31, 32-33, 91
  - Albite granite in 38
  - Marble in 55, 88
  - Metasediments in 89
  - Syncline in 53
- Dungannon Tp.:
  - Umfraville Gabbro in 32, 45
- Egan Creek 5
- Egan Lake 4, 7, 98
- Egan Lake dome 53
- Eldorado, village of:
  - Copper smelter in 64
- Elzevir-Ashby dome 52
- Emily mine 82-83
- Epidote 12, 26, 28, 29, 30
  - In albite granite 35
  - In almandine amphibolite facies rocks 58
- Epidotized bomb 14
- Epidotized lapilli 14
- Exploration, notes 1, 56, 62, 64
- Farming 3
- Faraday Tp., notes 45
- Faulting 30, 49, 53-54
- Faults 42, 47, 49, 52, 54, 63
- Feldspathic metagreywacke 23, 88, 89, 90
  - Calcareous 25, 26
  - Foliated 20
  - In table 22
  - Photos 24
  - Spectrographic analyses of 60
  - *See also:* Metagreywacke.
- Feldspathic metasandstone 8
  - *See also:* Metasediments.
- Felsic flow rocks 11, 16, 31
  - *See also:* Metavolcanics.
- Felsic intrusive rocks 41
- Felsic lapilli metatuff:
  - Photo 17
- Felsic metavolcanics 8, 10, 16-18, 31, 69
  - In rusty schists 65
  - In Tudor Tp. 46
  - In Turriff metavolcanics 32
  - Near Jordan Lake 98
  - Near Thanet Complex 83
  - Subdivided 11
  - *See also:* Metavolcanics.
- Felsic pyroclastic rocks 16, 33, 59
- Felsic tactite 29, 30
- Felsic tuff 14
- Felsic volcanic rocks 31
  - *See also:* Metavolcanics.
- Fishing 3
- Flowage rocks 28, 29
- Flow rocks 12, 15, 16, 23, 31, 98
- Fluorite 48, 49, 89
- Folding 28, 30
- Folds 4, 5, 44, 52-53
  - *See also:* Anticlines; Synclines.
- Foliated rocks 14, 16, 20, 26, 33, 38
- Foliation 4, 18
- Gabbro 8, 39, 84, 85, 86
  - Chemical analyses, table 40
  - Dikes 42, 44, 45
  - In Thanet Complex 51
  - Modal analyses, table 40
  - Near John Lake 46
  - Uralitized 36, 73
    - Photo 43
  - *See also:* Metagabbro.
- Gabbro-diabase 84
- Gabbroic complex 8
- Gabbroic rocks 4, 36, 41, 43, 44
- Galena 87, 88, 90, 91
  - In calcite vein 49, 55, 56
- Galena-bearing calcite veins 92, 94, 95
- Galena-bearing quartz vein 89
- Game 3
- Garnet 12, 16, 22, 80
  - Andraditic 30, 78, 82
  - In almandine amphibolite facies rocks 58
  - In mafic metavolcanics 59, 65, 67
  - In mafic tactite 83, 97
- Garnetiferous biotite-plagioclase-quartz gneiss 14, 18
- Garnet isograd, notes 10
- Gastropod shells 98
- Gawley Creek stocks 48, 54
- Geological mapping:
  - By The International Nickel Co. of Canada Ltd., notes 56
  - Macassa Gold Mines Ltd.:
    - Sketch map 73
- Geological work, previous 3

PAGE
Geology:
  Economic ... 55-98
  General ... 8-52
  Pleistocene ... 4-8
  Structural ... 52-55
Geophysical surveys, notes:
  By The International Nickel Co. of Canada Ltd. ... 56
  By Stratmat Mines Ltd. ... 65
Gilmour, village of ... 3
Gin Lake ... 53
Glacial deposits ... 5, 6, 7
Glacial striae ... 6
Glaciofluvial deposits ... 5, 6, 7
Glaciolacustrine deposits ... 7
Glanmire Complex ... 37, 43, 47, 48, 52, 54
  Albite granite in ... 36, 38
  In Tudor Tp. ... 33
  Mafic tactite in ... 29
  Quartz vein in ... 69-70
  Syncline in ... 53
Glanmire Lake ... 36, 80, 98
Gneiss ... 35, 70
  Calc-silicate ... 85, 96
  Garnet-biotite-plagioclase-quartz ... 18
  Hornblende-plagioclase ... 39
Gold ... 55, 56, 60, 62, 87
  Assay notes ... 64, 65, 90
  Deposits ... 63-70
  Production, notes ... 63
Gold-bearing quartz veins, notes ... 95
Gold-bearing schists ... 56
Granite ... 37, 77, 87
  Albite ... 33, 36
  Chemical analyses ... 34, 38
  Dikes ... 30, 37
  Modal analyses ... 34, 38
  Pegmatite ... 43, 44, 47, 48
    Dikes ... 42, 45
  Sills ... 30
  Sodic ... 35
  Stocks ... 38, 41, 50
Granoblastic texture ... 15
Granodiorite ... 8, 33, 42, 43
  In Glanmire Complex ... 36
  In Jocko Lake Complex ... 44
  In Limerick Tp. ... 38
Granodiorite-trondhjemite ... 45
Granophyre ... 33
Graphite ... 16, 20, 26, 28, 59, 95
  In almandine amphibolite facies rocks ... 58
  In greenschist facies rocks ... 97
  In table ... 19
Graphitic schists, notes and table ... 18, 59
Graphitic slate, table ... 18
Grassy Lake quartzite ... 32
Gravel pit ... 81
Greenschist facies rocks ... 10, 11, 25, 26, 97
  Arsenopyrite in ... 58, 62
  In Tudor Tp. ... 38
  Marble in ... 29
  Metagreywacke in ... 23
  Near Jordan Lake ... 98
  Pyrite in ... 69
  Quartz veins in ... 58, 63, 68
Grenville Province ... 8

PAGE
Grenville series rocks ... 92
Grimsthorpe-Barrie area, striae ... 6
Grimsthorpe stocks ... 33, 38, 52
Grimsthorpe Tp., properties ... 41, 56, 65
Ground moraine ... 7
Grunerite ... 16
Gull River Formation ... 49
Haliburton region ... 5
Hastings co., soil types, note ... 7
Hastings Road, properties ... 2, 3, 42, 90, 94-95
  Iron-titanium oxide minerals ... 85
  Marble ... 30
  Orton mine ... 84
  Quartz fissure vein ... 89
  Titaniferous magnetite ... 86
Hematite ... 42
  Specular ... 30
Hematite-ilmenite-rutile ... 51
Hemoilmenite ... 42, 51
Higman mine ... 70
Hill and Curshaw, Messrs. ... 95
Hollandia vein ... 93
Hornblende diorite ... 39, 44, 46
Hornblende gabbro dikes ... 42
Hornblende hornfels facies rocks ... 10, 26, 29
Hornblende metasediments ... 25, 26, 60
  See also: Metasediments.
Hornblende-quartz-plagioclase gneiss, notes and table ... 11, 14, 39
Hornblende schists ... 87
Howard Smith Paper Mill Ltd. ... 3
Hydrothermal alteration ... 58, 60, 75
Ice movement ... 6
Ilmenite ... 50, 51, 77, 84, 85
Ilmenomagnetite ... 51, 55, 84, 85
  Stringers ... 43
Industrial minerals ... 96-98
Intermediate metavolcanics ... 8
  See also: Metavolcanics.
International Nickel Co. ... 56, 70
  See also: International Nickel Co. of Canada Ltd., The.
International Nickel Co. of Canada Ltd., The ... 56, 57
  See also: St. Charles mine.
Intrusions ... 8, 10, 12, 16, 20, 25, 60
  In table ... 9
  In Tudor Tp. ... 15
  Near Beaver Creek ... 36
  See also: Beaver Creek Complex; Gawley Creek stocks; Glanmire Complex; Jocko Lake Complex; Lingham Lake Complex; Mount Moriah Syenite; Thanet Complex; Tudor Gabbro; Umfraville Gabbro; Wadsworth Trondhjemite.
Intrusive breccia ... 36, 37
Iron ... 55, 56, 80, 82
Iron and titanium ... 77-87
Iron formation ... 10, 18, 31, 32, 50
  In Limerick Tp. ... 84
  In Turriff metavolcanics ... 77
  Thickness of ... 83
Iron ore ... 55
Iron oxide minerals ... 20, 29

PAGE
Iron pyrites 82, 95
Iron-titanium oxide minerals .. 12, 39, 45, 71, 96
  In Bancroft-Madoc area 77
  In mafic stocks 50-51
  In Tudor Gabbro 70, 84, 85
Jocko Lake 5
Jocko Lake Complex 51, 53, 83, 96
  Report on 44-45
John Lake 46
Jointing 5
Joints 26, 62
Jordan Creek 94
Jordan Creek Syncline 52
Jordan Lake 98
Jordan River 5
Kaladar, village of 3
Katherine lead mine 90
Kesterman, W., of Belleville 93
Lacustrine deposits 6
Lake Ontario:
  Drainage basin 5
  Homocline 4
  Lobe of Wisconsin ice sheet 6
Lake Tp., notes on 30, 32, 42, 90
Lapilli 14
Lapilli metatuff 11
Lapilli tuff 16
Layered rocks 42
  Amphibolite, notes and photos 13, 14
Lead: 49-56
  Assay, notes 89, 92
  Deposits 88-95
  In table 61
  Production, notes 55
  See also: Galena.
Lead and zinc 87-95
Lee mine 80
Leverin, H. A., of Mines Branch Laboratory:
  Analyses by 86
Limerick Lake 4, 5, 7, 39, 46, 51
  Fault 52, 54
  Stocks 39
  Syncline near 53
Limerick Lake Fault 52, 54
Limerick Tp.:
  Dikes 43, 46, 47
  Folds 52, 53
  Granodiorite 38
  Little Wadsworth Lake 54
  Marble 97
  Marl 98
  Quartz-bearing diorite 44
  Quartz vein 49
  Schists 61
  Stocks 33, 48
  Turriff metavolcanics 50
  Umfraville Gabbro 45
Limerick Tp., properties:
  Con. I, lot 1 .... 56, 65
  Con. II, lots 1, 2, 21, 22 .... 56, 91, 92, 98
  Con. III, lot 2 .... 56, 92
  Con. IV, lots 7, 17-20 .... 59, 96, 98
  Con. V, lots 8-10, 15, 16, 26-28, 30 .... 46, 72
  Con. VI, lots 15, 16, 18, 27-30 .... 46, 72, 84
  Con. VII, lots 9, 19 .... 59, 70

PAGE
  Con. VIII, lots 11, 29, 30, 31 .. 28, 59, 72, 84
  Con. IX, lot 29 59
  Con. X, lots 3 and 4 59
  Con. XII, lot 19 77
  Con. XV, lots 28 and 29 86
Limestone 18, 49, 82
Lineaments 53, 54, 90
  See also: Faults.
Lingham Lake Complex 31, 33, 39, 41-42, 52, 59, 63
  Anticline near 53
  Arsenopyrite in 68-69
  Copper in 70
  Granodiorite 33
  Iron-titanium oxide minerals in 51
  Metapyroxenite 96
  Nickel in 56
  Quartz-carbonate fissure veins 54
  Tonalite 71
  Ultramafic rocks 76
  Uralitized gabbro 46
Lithographic limestone 49
Little Wadsworth Lake 54, 91
Lombard and Co., of Boston, Messrs. 91
Louada Exploration and Development Co. Ltd. 76n
Lumbering 3
Macassa Gold Mines Ltd. 56, 65, 72-75
  Surface plan, sketch 73
  Vertical section, sketch 74
McDonalds siding 78, 84
McMurray, V. A., of Gilmour 65, 67
McMurray, W. A. 91
McMurray occurrence, report on 62, 65-67
  Sketch map 66
Madawaska highlands 5, 49
Madawaska River system 5
Madoc-Bancroft area, notes 8, 31, 55
Madoc Tp., notes 6, 49, 64, 97
Mafic dikes 8, 18, 47, 49, 92
Mafic flow rocks 11, 12, 15
  See also: Metavolcanics.
Mafic intrusive rocks 29, 39-47, 56, 70, 71
  See also: Diorite; Gabbro.
Mafic metavolcanics 10, 16, 36, 63, 69, 98
  Arsenopyrite in 67
  Carbonate metasediments near 78
  Garnet in 65
  In Burnt Lake formation 32
  In greenschist facies 62
  In Oak Lake formation 31
  Iron formation in 83
  Near intrusions 15
  Near Steenburg Lake 23
  Pillow lavas in 30
Mafic phases of rocks, notes 41
Mafic pyroclastic rocks, notes and photo .. 11, 14
Mafic sills 8, 47, 49, 92
Mafic tactite 82, 97
Magmatic segregation deposits 77, 84-86
Magnesium, notes and table 20, 86
Magnetite 12, 78, 80, 82, 84
  In anorthositic gabbro 86
  In Baker mine 81
  In Emily deposit 83
  In greenschist facies metavolcanics 50

PAGE
  In mafic tactite 30
  In metaperidotite 76
  In schists 59, 67, 87
  In Thanet Complex 51
  In Tudor Gabbro 77
  In Umfraville stocks 48
Manganese 60, 61, 71
Mann Lake 43, 84
Mapping, notes on 10, 42, 43, 45
Maps:
  Aeromagnetic, notes on 3, 56
  Geological, coloured .... *back pocket*
  Sketch, properties 57, 66, 73, 79, 81, 85
Marble 53, 54, 78, 91, 96-97
  Analyses, chemical, notes 30
  Calcite fissure vein in 90
  Calcitic, notes and photos 25, 27
  Dolomitic 25, 29, 30
  For building stones 55
  In Beaver Creek Complex 80
  In Dungannon formation 38, 88, 89
  In Glanmire Complex 36
  Near Egan Lake 4
  Pyrite in 62
  Tremolitic 26, 28
  With iron formation 84
Marble quarry 55
Marl 7, 55, 98
Marmora area, notes 6
Maynooth, village of 3
Mayo Lake 53
Mayo Tp., notes 32, 53
Meta-agglomerate 11
  See also: Metavolcanics.
Meta-andesite 50
  See also: Metavolcanics.
Meta-arkose 23
  See also: Metasediments.
Metabasalt 16
  See also: Metavolcanics.
Metaconglomerate 8, 23, 24, 25, 31, 53
  See also: Metasediments.
Metadiorite 38, 39, 46, 47
  See also: Diorite.
Metagabbro 36, 38, 39, 43, 46, 47
  See also: Gabbro.
Metagreywacke 4, 22, 23, 45, 53, 91
  In Dungannon formation 31
  In Jocko Lake Complex 44
  See also: Metasediments.
Metagreywacke, feldspathic:
  See: Feldspathic metagreywacke.
Metamorphic rocks 11, 15, 18, 26, 30, 33
  Aureoles .... 41-63 *passim*, 97
  Differentiation 29
  Grades, notes 8, 10
Metamorphism 38, 55, 96
  Contact 20
  Figure .... *back pocket*
  Regional 12, 16, 35, 39, 50
Metaperidotite .... 39, 4[illegible] 76, 96
Metapyroxenite 75, 84
  Actinolite in 73
  Dikes 43, 44, 70, 72
  In Jocko Lake Complex 96
  In Lingham Lake Complex 41

PAGE
  In Thanet Complex 56
  Talc in 76
Metarhyolite, notes and photo 17, 31
Metasandstone, calcareous 8, 20, 23, 28, 50, 52
  In Dungannon formation 33
  In Vansickle formation 32
  Subdivisions of, table 21
  Table 22
Metasedimentary-metavolcanic rocks 30, 50
  See also: Metasediments; Metavolcanics.
Metasediments 5, 6, 8, 18-30, 31, 58, 90
  Calcite vein in 87
  In Dungannon formation 32, 33, 53, 88, 89
  In Limerick Tp. 4, 47, 52
  In Tudor Tp. 42, 48
  In Wadsworth stocks 38
  Magnetite in 50
  Near Beaver Creek 11
  Photo 25
  Rusty schists in 59, 60
  Spectrographic analyses, table 61
  Tables of 9, 22
  See also: Metagreywacke; Metasandstone, calcareous.
Metasiltstone 8, 25, 28, 50, 52, 91
  Calcareous 20, 23, 26, 32, 33
  Tables 21, 22
Metasomatism 29, 50, 70, 77, 78-83
Metasubarkose, notes and photo 23, 24
Metatuff 11, 16, 17, 18, 65, 69
  See also: Tuff.
Metavolcanics 10-18, 20, 50
  Analyses, chemical 15
  Andesitic 31
  Exposure of 6
  Felsic 25, 55, 62, 65, 69
  Garnet in 59
  Gold, trace in 67
  In Limerick Tp. 47
  In Thanet Complex 83
  In Tudor Tp. 46
  In Vansickle formation 32
  Mafic 23, 30, 41, 42
  Near Jordan Lake 98
  Photo 13
  Quartz vein in 87
  Rusty schists in 58
  With iron formation 77
  See also: Felsic metavolcanics; Mafic metavolcanics; Metatuff; Pyroclastic rocks.
Methuen Tp. 32
Millbridge, village of 3, 84
Millbridge Syncline 52, 53
Mineral assemblages 10, 11, 29, 58, 59
Mining activity, notes 55-57
Moira River 5, 12
Moira River Fault 54
Molybdenum, notes and table 60, 61
Monzonite 47, 48
Moraine, ground 7
Mount Moriah Syenite 48, 50, 52
Murphy Corners Anticline 10, 14, 32, 52, 53
Murphy mine 91, 94
Natural resources 3

PAGE
Nickel 43, 55, 70-77
  In Lingham Lake Complex 41, 56
  In rusty schists 60
  In tables 61, 71, 86
  Trace 62
Nomenclature of metasediments 18
Nomenclature of metavolcanics 11
Nonmetallic and industrial minerals 96-98
Norms of metavolcanics, table 15

Oak Lake formation 8, 30, 31-32, 50, 65
Oligoclase isograd 10
  Figure *back pocket*
Olivine gabbro 39, 40, 46
  In table 40
Ordovician rocks, notes and table 8, 9, 48, 49
Ormsby dome 52, 53
Ormsby Junction, village of 2, 3
Orton mine 43, 84-85, 87
  Chemical analyses of rocks, table 86
  Sketch map 85
Ottawa River drainage basin 5
Ottawa Valley 49
Outlier, Ordovician 8, 48

Paleozoic rocks, notes and table 3, 4, 9
  See also: Ordovician rocks.
Paleozoic sedimentary rocks 48-49
Pamelia Formation 49
Para-amphibolite, notes, table 20, 22, 25, 26
Peat 7
Pebble conglomerate 23
Pegmatite 44, 48
  Dikes 33, 38
  Granite 43, 47
  Sills 30
  Syenite 37
Pegmatitic diorite 42, 45
Pegmatitic gabbro 42, 44, 45
Pentlandite 75, 76
Peridotite 39, 43, 46
Petrographic data 16
Phlogopite 25, 26, 28
Phlogopitic marble 25, 26, 28
Phosphorus 80, 82
Physiography 4-7
Pillow lavas 30
  See also: Metavolcanics.
Pillow structures 12
Pistacite 46, 78, 80, 82, 83
  See also: Epidote.
Pleistocene deposits 5, 8
Pleistocene geology 4-7
  Figure *back pocket*
Polymictic metaconglomerate, notes and photo 23, 24
Porphyritic rocks 12, 33, 35, 38, 48
Precious metals 58-96
Prospecting activity 55-56
Proterozoic rocks, notes and table 8, 9
Pulpwood 3
Pyrite 18, 30, 70, 80, 82, 85
  Assay notes 64
  In albite granite 35
  In calcite veins 49, 83, 89
  In McMurray occurrence 65
  In marble 26

PAGE
  In metatuff 69
  In metavolcanics 67
  In quartz vein 63, 90
  In rusty schists 10, 55, 58, 59, 60
Pyritiferous schists, notes and table 18
Pyroclastic rocks 11, 16, 31, 33, 59
  Photo 14
  See also: Metavolcanics.
Pyroxenite 39, 43, 45, 46
Pyrrhotite 10, 12, 28, 51, 59, 71, 72, 76
  In carbonate metasediments 55
  In carbonatized zone 75
  In McMurray occurrence 65
  In mafic tactite 30
  In magnetite 80, 82
  In metapyroxenite dikes 70
  In quartz veins 62, 63
  In rusty schists 50, 58, 60
  In silicified metavolcanics 67
Pyrrhotite-bearing schists 10, 55, 72

Quartz 49, 70, 76, 77, 88, 92
  Veins 15, 47, 54, 58
    Arsenopyrite in 62, 65, 68, 90
    Calcite in 82, 87
    Chalcopyrite in 89
    Gold in 67
    Pyrite in 63
    Silver in 67
    Tourmaline in 37, 69
Quartz-bearing diorite 39, 41, 44, 45, 71
Quartz-carbonate veins 12, 47, 54, 68, 69
Quartz fissure veins 8, 49-50, 53, 54
  Galena in 87, 89, 90
Quartzite, Grassy Lake 32
Quartz monzonite 36, 47, 48
Quinlan Lake occurrence 68

Ramsey, William, of Millbridge 89
Ramsey prospect 96
Recent deposits, in table 8
Reelman, George 93
Reelman occurrence 93
Rhyodacitic welded tuff 38
Rhyolite 16, 68, 69
Ricketts iron mine 87
Ricketts property 86
Ritchie, Samuel J. 56
Roberts lead occurrence 92-93
Robinson Lake 5
Robinson Lake Syncline 10, 32, 53
Robson, B.C., survey by 83
Roofing granules 55, 98
Rusty schists 58, 59, 65, 67, 87, 88
  Chemical analyses, table 60
  Spectrographic analyses, table 61
  See also: Metasediments; Schists, rusty.
Rutile 51, 77

St. Charles mine 55, 77, 78
  Sketch map of 79
St. Ola, village of 3, 11, 23
St. Ola Fault 47, 52, 54
St. Ola Lake 5
Sand and gravel deposits 6, 7, 55, 98
  See also: Glacial deposits.
Sandstone, notes and table 18, 23, 49
  See also: Metasediments.

PAGE

Sawmills 3
Scapolite 26, 28
Schists, rusty 10, 15, 16, 54, 58, 65, 88
  Chalcopyrite in 59, 67, 70
  Chemical analyses, table 60
  Magnetite in 67
  Pyrrhotite in 50
  Spectrographic analyses, table 61
  Sphalerite in 87
Sedimentary rocks 8, 49, 58, 60
  See also: Metasediments.
Sedimentation, types of, table 18
Serpentine 39, 76
Shadow Lake Formation 48, 49
Shafts 88, 92, 93, 94, 95
Shale 16, 49, 58, 59
  In table 18
  See also: Metasediments.
Sheared rocks 25, 54, 59, 67
Shearing 16, 53
Shear zones 42, 54, 58
Sheppard's Gold Mine 70
Siliceous iron formation 50, 77
  See also: Iron formation.
Siliceous metasediments 53, 58, 59, 60, 87
  In Burnt Lake formation 32
  In Dungannon formation 33
  Lithology of 20
  See also: Metasediments.
Sills 29, 30, 46
  Mafic 8, 47, 49, 92
Siltstone, notes and table 18, 49
  See also: Metasiltstone.
Silver 55, 60, 62, 67, 95
  Assay notes 64, 89, 92
  In table 61
  Trace 68, 69, 70, 87
    Assay notes 63, 65, 90
Slate 18
  See also: Metasediments.
Smelter, copper 64
Smith's mine 95
Snow Road 2
Sodic granitic rocks 33, 36, 38, 77
  Age of 41
  Chemical analyses of 34
  See also: Granite.
Sodic rhyolite 16
Soils 7
Spectrographic analyses, notes, tables 60, 61
Specular hematite 30, 82
  See also: Hematite.
Specularite 82
Sphalerite 59, 60, 75, 88
  In calcite veins 49, 89
  In quartz fissure veins 87
Sphene 12, 15, 30, 48, 58
Spilite 16
Staurolite 18
Staurolite isograd, notes 10
Steenburg Creek 7
Steenburg Lake 7, 11, 23, 80
Stewart lead occurrence 88
Stocks 8, 38, 39, 50, 54
  Albite granite 33, 35, 41
  See also: Intrusions.

PAGE

Stone 55
  See also: Building stone; Marble.
Stratigraphy 30
  Figure .... *back pocket*
Stratmat Mines Ltd. 65
Structural geology 52-55
  Figure .... *back pocket*
Sulphide mineralization 58
Sulphide minerals 15, 20, 72, 75, 76, 89
  In calcite 87
  In marble 29, 97
  See also: Chalcopyrite; Galena; Pentlandite;
    Pyrite; Pyrrhotite; Sphalerite;
    Tetrahedrite, argentiferous.
Sulphur 80, 82, 84
Survey, notes 1, 56, 76, 82, 84
Syenite 8, 33, 35, 38, 48
  Breccia 37
  Dikes 43, 47
  Stocks 39, 41
Syenitic rocks 30, 34, 35, 47-48, 77
Synclines 10, 32, 52, 53

Tactite:
  Felsic 29, 30
  Mafic 82, 83, 97
  Magnetite-rich 78, 80
  Photo 36
Talc 39, 55, 73, 76, 96
Terrazzo 55, 96, 97, 98
Tertiary rocks 49
Tetrahedrite, argentiferous 87
Thanet Complex ..39, 43-44, 51, 52, 56, 83, 97
  Cobalt in 71
  Copper in 70
  Metaperidotite in 96
  Metapyroxenite in 75
Till 7
Timber 3
Titaniferous magnetite 84, 86
Titanium 55, 77, 80, 82, 83, 84
  In tables 61, 71, 86
Tivani Steel Co., of Belleville 55, 84
Tonalite 39, 41, 44, 73, 75
  Dikes 72
  Spectrographic analyses 71
Tourmaline 48, 87, 89, 90, 95, 96
  In quartz veins 37, 49, 62, 68, 69, 82
Tremolite 28, 51, 82, 96
Tremolitic marble 25, 26, 28
  See also: Marble.
Trent River system 5
Triana Explorations Ltd. 56, 76-77
Trondhjemite 8, 33, 82
  Dikes 68, 78
  In Limerick Tp. 44, 66
  In Tudor Tp. 36, 37, 42, 43, 83
  Modal analyses 41
  Stocks 35, 38
  See also: Wadsworth Trondhjemite.
Tudor Gabbro 4, 12, 36, 42-43, 96
  Anomaly in 51
  Carbonate metasediments in 48, 97
  Iron-titanium oxide in 70, 85
  Near Elzevir-Ashby dome 52
  Orton mine in 84
  Photo 43

PAGE
  Rusty schists in 59
  St. Charles mine in 77
  Table 40
Tudor metavolcanics 8, 30, 52, 63, 78
  In Lingham Lake Complex 63
  Iron formation in 31, 83
  Millbridge Syncline in 53
  Near Jordan Lake 98
Tudor Tp., properties:
  Blackburn lead mine 88
  "Block 8", lot 9 93
  Con. B, lots 23, 28, 30 93
  Con. I, lots 1, 4, 7-9 ....49, 68, 98
  Con. II, lots 2, 6, 11 ....46, 68, 88
  Con. III, lots 2, 3, 4, 5, 33, 34 ..63, 76, 90, 95
  Con. IV, lots 2, 3, 34 ....76, 94
  Con. V, lots 9, 10 59
  Con. VI, lot 1 68
  Con. VII, lots 16-24, 33, 34 ....96, 98
  Con. VIII, lot 24 43
  Con. IX, lots 16-18, 28 ....43, 59
  Con. X, lots 1, 7, 13, 17, 18 ...59, 69, 70, 83
  Con. XI, lots 17, 19 ....78, 87
  Con. XII, lots 5, 25 ....68, 69
  Con. XIII, lots 5, 6, 11, 16, 26....46, 55, 69
  Con. XIV, lots 4, 29 ....69, 91
  Con. XV, lots 5, 8 ....69, 87
  Con. XVII, lot 12 32
  Con. XVIII, lots 9, 17, 18 ....32, 80, 81
  Con. XIX, lots 3, 7 ....82, 83
  Hastings Road lots 84, 89, 90, 94-95
  Murphy mine 91
  Orton mine 55
  Range 14, lots 28, 29 91
  St. Charles mine 55
Tuff 14, 16, 38
  See also: Metatuff; Metavolcanics.
Tuffaceous rocks 16, 18, 58
Turriff metavolcanics 8, 30, 31, 32, 50
  Iron formation in 77, 83
Twomile Lake 84
Twomile Lake Fault 54

Ultramafic rocks 39, 41, 51, 56, 70, 76
Umfraville Gabbro 5, 6, 39, 41, 48, 52, 97
  Anomaly in 51
  Description of 45-46
  Iron-titanium oxide in 70
  Magnetite in 77
  Near Ormsby dome 53
  Table 40
Uralitized diorite 41, 44, 72, 73, 75
  In table 40
  Spectrographic analyses, table 71

PAGE
Uralitized gabbro 41, 45, 46, 73, 75, 84
  Chemical analyses, notes and table 40, 42
  In Glanmire Complex 36
  In Jocko Lake Complex 44
  In Thanet Complex 51, 72
  Photo 43
  Spectrographic analyses, table 71
Uranium-lead systems in zircon 31
Urbach Lake Anticline 52, 53

Vanadium:
  In tables 61, 71
  Test for 80, 82
Vansickle formation 8, 30, 88, 91-92
  Syncline in 53
  Thickness of 32
Varved clay 7
Veins:
  Calcite ....[illegible], 49-50, 53, 54, 80, 83, 97
    Galena in 55, 56, 88
    Silver, trace 87
  Chalcopyrite 75, 80
  Pyrite 62
  Pyrrhotite 62
  Quartz 47, 49-50, 53, 54, 69, 83
    Arsenopyrite in 65, 67, 68
    Calcite in 82
    Pyrite in 59, 62, 85
    Rutile in 77
    Silver, trace 87
    Tourmaline 37
Vesuvianite 29, 30
Volcanic activity 31
Volcanic rocks 5, 31, 58
  Structures 14
  See also: Metavolcanics.

Wadsworth Lake 50
Wadsworth Lake Mining Co.:
  See: McMurray occurrence.
Wadsworth Trondhjemite ..33, 35, 38, 82, 83, 97
  In Elzevir-Ashby dome 52
  Mafic tactite in 29
  Metaconglomerate in 23
  Syncline near 53
West Black River 5
Wisconsin glacial stage 6
Wolf Lake 88, 98
Wollaston Tp., notes 6, 32, 43, 45, 52, 53

York River 5

Zinc, notes and table 55, 59, 61, 87-95
  See also: Sphalerite.
Zircon, notes and table 31, 48, 58, 61

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